

6 (PRTS)

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DESCRIPTION

PHOSPHORUS-CONTAINING COMPOUND

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TECHNICAL FIELD

The present invention relates to a phosphorus-containing compound useful as additives (in particular, flame retardants, plasticizers, stabilizers, etc) for various materials (e.g., compositions including hot-melt adhesives, thermosensitive tackifiers, delayed tack adhesives, image-receiving materials for forming an image by thermal transfer, photosensitizers for color photography, melttable inks for ink jet, shock-absorbing materials, pencil leads, and so on), further for organic compounds, particularly organic polymer compounds (e.g., vinyl chloride resins), lubricants, and heat transfer medium, etc, and relates to a process for producing the same. The phosphorous-containing compound is particularly useful as flame retardants, plasticizers, stabilizers, and the like.

BACKGROUND ART

Conventionally, organic polymers are molded or formed, with adding additives such as flame retardant, stabilizer in order to impart flame retardancy and stability to the organic polymers. Such additives are exemplified inorganic compounds, phosphorus-containing

compounds (e.g., aromatic phosphoric esters (phosphates), phosphorus-containing aliphatic condensed compounds), halogen-containing compounds (e.g., organic halogen compounds, halogen-containing organic phosphorus compound). Among these additives, the halogen-containing compounds can impart high flame retardancy. Typical halogen-containing compounds include, for example, tetrabromo-diphenylether, tetrabromo-bisphenol A, tri(dichloropropyl)phosphate, and tri(dibromopropyl) phosphate.

The halogen-containing compounds are, however, thermally decomposed under a resin-molding process to generate a hydrogen halide, and so the hydrogen halide not only corrodes a metal mold and deteriorates characteristics of resins but also causes the working environment worse. Further, poisoned gases (hydrogen halides) generated by combustion of the halogen-containing compounds affect human bodies and environments adversely.

Meanwhile, among non-halogenous series additives, since inorganic compounds such as metal hydroxide (e.g., magnesium hydroxide, aluminum hydroxide) and metal oxide (e.g., antimony oxide, alumina) have a low flame retardability, large amount of inorganic compounds is required in order to obtain a desired flame retardancy. Therefore, the properties of resin are liable to be deteriorated.

Moreover, as non-halogenous additives expressing

relatively high flame-retardantability, aromatic phosphoric esters (phosphates) such as triphenylphosphate (hereinafter, occasionally abbreviated as TPP) and tricresylphosphate are used. In particular, since TPP 5 shows excellent flame retardancy, TPP is generally used. However, the volatility of TPP is high, and TPP is volatilized in a resin composition-molding process, to contaminate metal with deteriorating the external appearance of the molded articles.

10 Further, even though the above mentioned halogen-series additives and non-halogen-series additives are used in combination, flame-retardability of the articles is still insufficient.

15 Incidentally, Japanese Patent Publication No. 19858/1976 (JP-51-19858B), Japanese Patent Publication No. 18336/1990 (JP-2-18336B) and Japanese Patent Application Laid-Open No. 1079/1993 (JP-5-1079A) disclose condensed organic phosphorus compounds having low volatility in order to enhance flame retardancy for a variety of resins 20 (e.g., polyester resins, polyamide resins, polycarbonate resins). Particularly, Japanese Patent Publication No. 19858/1976 (JP-51-19858B) discloses a method of producing the condensed phosphate mentioned above by reacting arylenediol and diarylphosphochloride. However, 25 although heat resistance of these condensed phosphates is more excellent than that of TPP, it is difficult to impart high flame retardancy to resins.

Incidentally, Japanese Patent Application Laid-Open No. 55947/1982 (JP-57-55947A) discloses a halogen-containing resin composition obtained by adding a salt of organic acid with zinc, a salt of organic acid with Group IIa metal, an epoxy compound and/or an organic phosphite compound, and a specific organic phosphate compound to a halogen-containing resin, which is excellent in stability (particularly, stability of weather resistance). As the organic phosphate compounds, there are disclosed phosphoric esters (phosphates) of divalent or trivalent alcohols. The divalent or trivalent alcohols include ethylene glycol, triethylene glycol, cyclohexanediol, 1,4-phenyldimethanol, hydrogenated bisphenol.

Moreover, bicyclo phosphate compounds are disclosed in many publications, for example, ORGANIC PHOSPHOROUS COMPOUNDS vol. 6 (a Division of John Wiley & Sons. Inc.). Further, Japanese Patent Publication No. 14072/1991 (JP-3-14072B), Japanese Patent Application Laid-Open No. 35833/1999 (JP-11-35833A), Japanese Patent Application Laid-Open No. 286910/1997 (JP-9-286910A) and Japanese Patent Application Laid-Open No. 187451/1986 (JP-58-187451A) also disclose a variety of bicyclo phosphate compounds, and utilization of these compounds as an additive (e.g., flame retardant) for various resins.

However, the effect (e.g., flame-retardant effect) of the compounds is not sufficient yet.

It is an object of the present invention to provide

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a novel phosphorus-containing compound excellent in heat resistance and useful as flame retardant, plasticizer or stabilizer.

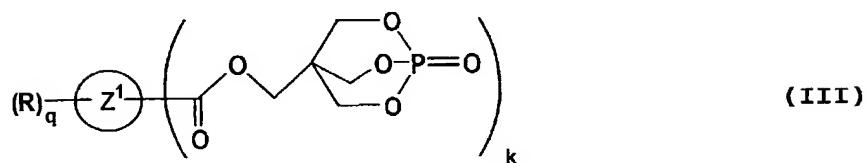
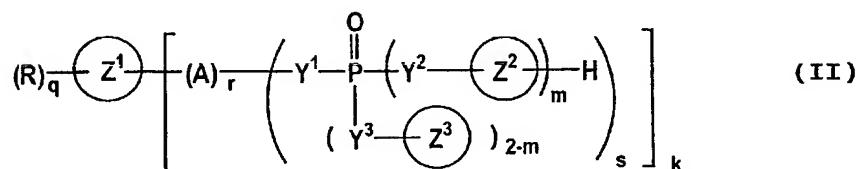
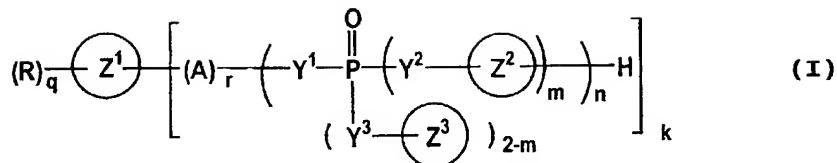
It is another object of the present invention to  
5 provide a phosphorus-containing compound having low  
volatility and capable of imparting high flame retardancy  
to resins.

It is still another object of the present invention  
to provide a process for producing a phosphorus-containing  
10 compound capable of imparting high flame retardancy to  
resins, with high yield and high purity by simple manner.

#### DISCLOSURE OF INVENTION

The inventors of the present invention made intensive  
15 studies to achieve the above objects and finally found that  
a phosphorus-containing compound having a specific ring  
structure remarkably improves flame retardancy of resins  
and is useful as plasticizer, stabilizer, etc. The present  
invention was accomplished based on the above findings.

20 That is, the phosphorus-containing compound of the  
present invention is represented by the following formula  
(I), (II) or (III):



wherein  $Z^1$ ,  $Z^2$  and  $Z^3$  are the same or different, each representing a cycloalkane ring, a cycloalkene ring, a polycyclic aliphatic hydrocarbon ring or an aromatic hydrocarbon ring, in which the rings may have a substituent;  $R$  represents a halogen atom, a hydroxyl group, a carboxyl group, a halocarboxyl (haloformyl) group, an alkyl group, an alkoxy group, an alkenyl group or an aryl group;  $A$  represents a polyvalent group corresponding to an alkane;  $Y^1$ ,  $Y^2$  and  $Y^3$  are the same or different, each representing  $-\text{O}-$ ,  $-\text{S}-$  or  $-\text{NR}^1-$

wherein  $R^1$  represents a hydrogen atom or an alkyl group;

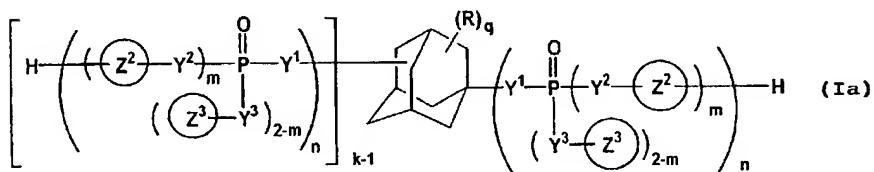
$k$  represents an integer of 1 to 6;  $m$  represents an

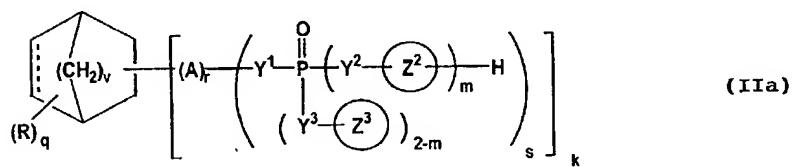
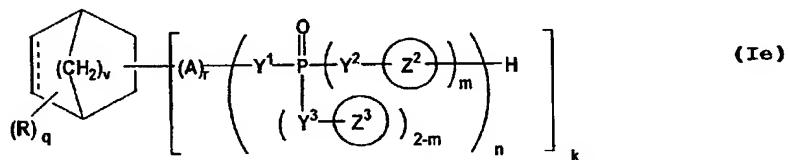
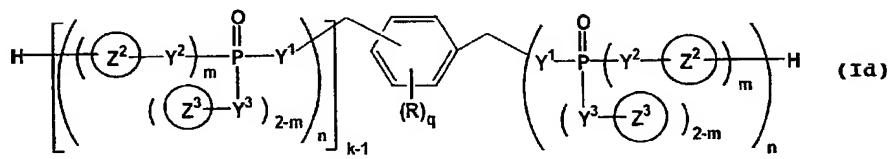
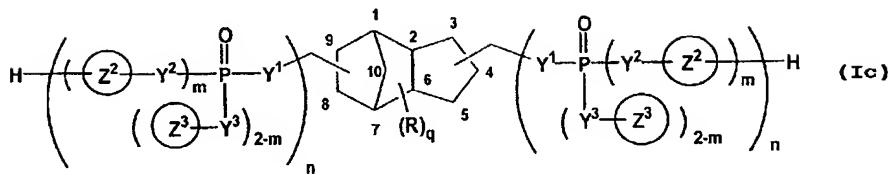
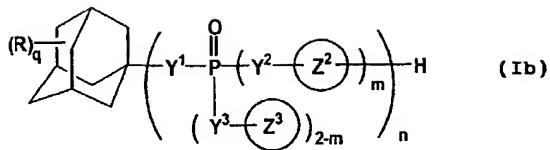
integer of 0 to 2; n represents an integer of not less than 1; q represents an integer of 0 to 5; r represents 0 or 1; s represents an integer of 1 to 4; and

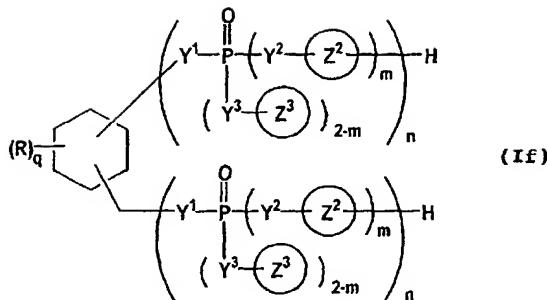
provided that when  $Z^1$  is a cyclohexane ring, q is 0, 5 and k is 1, factor r for A is 1; when  $Z^1$  is a cyclohexane ring, q is 0, and k is 2 to 6, at least one of plural factors r for A is 1; and when  $Z^1$  is a benzene ring and k is 1, the factor r for A is 1; when  $Z^1$  is a benzene ring and k is 2 to 6, at least one of plural factors r for A is 1.

10 The rings  $Z^1$ ,  $Z^2$  and  $Z^3$  each may be an aliphatic dicyclic hydrocarbon ring (e.g., a norbornane ring) or an aliphatic tricyclic hydrocarbon ring (e.g., an adamantane ring, a tricyclo[5.2.1.0<sup>2,6</sup>]decane ring), or a benzene ring. In the formula (I), the R may be a halogen atom, a hydroxyl group, a C<sub>1-4</sub>alkyl group, or a C<sub>1-4</sub>alkoxy group. The each  $Y^1$ ,  $Y^2$  and  $Y^3$  may represents -O-. The k may be 1 or 2, and n may be 1, and q may be 0 to 2. The phosphorus-containing compound represented by the formula (I), (II) or (III) may be a compound represented by the following formula (Ia).

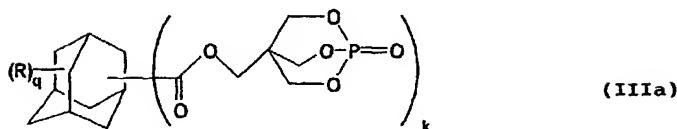
15 20 (Ib), (Ic), (Id), (Ie), (If), (IIa), or (IIIa):







(IIIf)



(IIIa)

wherein the following structure

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5 represents a single bond or a double bond; v is an integer of 0 to 2;  $Z^2$ ,  $Z^3$ , R,  $Y^1$ ,  $Y^2$ ,  $Y^3$ , k, m, n, q, r and s have the same meanings as defined above.

The present invention also includes a process for producing the phosphorus-containing compound.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a  $^1\text{H-NMR}$  spectrum for the adamantlyl bis(diphenylphosphate) obtained in Example A1.

15 Figure 2 is an infrared absorption spectrum for the adamantlyl bis(diphenylphosphate) obtained in Example A1.

Figure 3 is a  $^1\text{H-NMR}$  spectrum for the adamantlyl diphenylphosphate obtained in Example B1.

Figure 4 is an infrared absorption spectrum for the

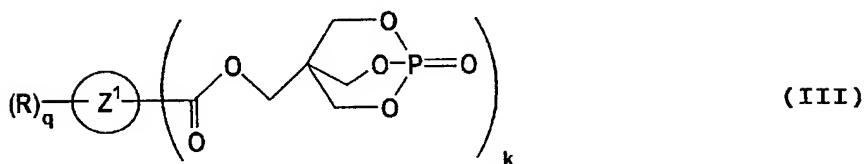
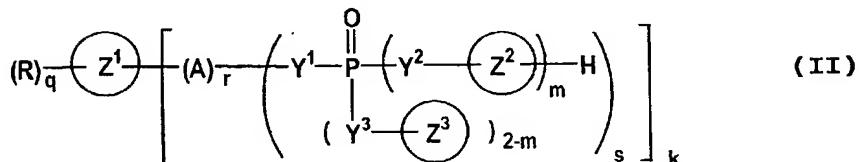
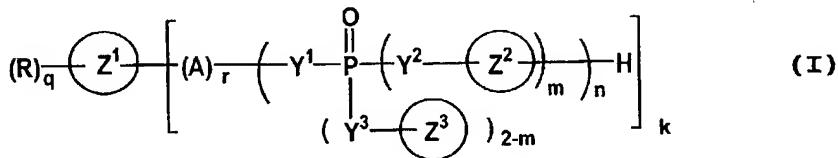
adamantylbis(diphenylphosphate) obtained in Example B1.

Figure 5 is a  $^1\text{H-NMR}$  spectrum for the  
(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)  
methyladamantanecarbonate obtained in Example F1.

5 Figure 6 is an infrared absorption spectrum for the  
(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)  
methyladamantanecarbonate obtained in Example F1.

#### BEST MODE FOR CARRYING OUT THE INVENTION

10 The phosphorus-containing compound of the present  
invention is represented by the following formulae (I),  
(II) or (III):



wherein  $z^1$ ,  $z^2$  and  $z^3$  are the same or different, each representing a cycloalkane ring, a cycloalkene ring, a polycyclic aliphatic hydrocarbon ring or an aromatic hydrocarbon ring, in which these rings may have a 5 substituent; R represents a halogen atom, a hydroxyl group, a carboxyl group, a halocarboxyl group, an alkyl group, an alkoxy group, an alkenyl group or an aryl group; A represents a polyvalent group corresponding to an alkane;  $y^1$ ,  $y^2$  and  $y^3$  are the same or different, each representing 10  $-O-$ ,  $-S-$  or  $-NR^1-$  wherein  $R^1$  represents a hydrogen atom or an alkyl group.

As cycloalkane rings represented by  $z^1$ ,  $z^2$ , and  $z^3$ , there are exemplified C<sub>4-20</sub>cycloalkane rings such as cyclobutane, cyclopentane, cyclohexane, cycloheptane, 15 cyclooctane, cyclononane, cyclododecane, cyclopentadecane, and cyclooctadecane rings (preferably C<sub>4-16</sub>cycloalkane rings, and more preferably C<sub>4-12</sub>cycloalkane rings). As cycloalkene rings, there are exemplified rings corresponding to the cycloalkane rings 20 [(e.g., C<sub>4-20</sub>cycloalkene rings such as cyclohexene ring and cyclooctene ring (preferably C<sub>4-16</sub>cycloalkene rings, and more preferably C<sub>4-12</sub>cycloalkene rings))].

As aliphatic polycyclic hydrocarbon rings represented by  $z^1$ ,  $z^2$  and  $z^3$ , aliphatic crosslinked 25 hydrocarbon rings and aliphatic condensed hydrocarbon rings are included.

As aliphatic crosslinked hydrocarbon rings, there

may be dicyclic or bicyclic hydrocarbon rings such as pinane, bornane, norpinane, and norbornane rings; tricyclic hydrocarbon rings such as homobrendane, adamantane, tricyclo[5.2.1.0<sup>2,6</sup>]decane, and tricyclo[4.3.1.1<sup>2,5</sup>]undecane rings; tetracyclic hydrocarbon rings such as tetracyclo[4.4.0.1<sup>2,5</sup>.1.7,10]dodecane and perhydro-1,4-methano-5,8-methanonaphthalene rings, etc; hydrogenated compounds of dimers of diens [e.g., hydrogenated compounds of dimers of cycloalkadienes such as cyclopentadiene, cyclohexadiene and cycloheptadiene, including, e.g., perhydro-4,7-methanoindene; dimers of butadiene (vinyl cyclohexene) or hydrogenated compounds thereof; dimers of butadiene and cyclopentadiene (vinyl norbornene) or hydrogenated compounds thereof]. The preferred crosslinked-cyclic hydrocarbon rings include dicyclic rings such as norbornane ring, and tricyclic rings such as adamantane and tricyclo[5.3.1.0<sup>2,6</sup>]decane rings, and the particularly preferred crosslinked-cyclic hydrocarbon rings are adamantane ring and tricyclo[5.2.1.0<sup>2,6</sup>]decane ring.

As condensed cyclic hydrocarbon rings, there may be mentioned, for example, a 5- to 8-membered cycloalkane-condensed ring such as perhydronaphthalene ring (decalin ring), perhydroanthracene ring, perhydrophenanthrene ring, perhydroacenaphthene ring, perhydrofluorene ring, perhydroindene ring, and perhydrophenalene ring.

Examples of aromatic hydrocarbon rings include

aromatic hydrocarbon rings having carbon numbers of 6 to 14 (preferably carbon numbers of 6 to 10) such as benzene ring and naphthalene ring. As the preferred aromatic hydrocarbon ring, there is exemplified benzene ring.

5         Halogen atoms represented by R include fluorine, chlorine, bromine, and iodine atoms. The preferred halogen atom is chlorine atom. As halocarboxyl groups, there are exemplified chlorocarboxyl group, bromocarboxyl group, and iodocarboxyl group. The preferred halocarboxyl group is chlorocarboxyl group.

10         Examples of alkyl groups include C<sub>1-8</sub>alkyl groups such as methyl, ethyl, n-propyl, isopropyl, isobutyl, t-butyl, t-pentyl, hexyl, isoctyl, t-octyl, and 2-ethylhexyl groups (preferably C<sub>1-6</sub>alkyl groups, more preferably C<sub>1-4</sub>alkyl groups, and particularly methyl, ethyl, isopropyl, and t-butyl groups).

15         The alkyl groups may have a substituent. As the substituent, there may be exemplified various substituents, for example, C<sub>6-18</sub>aryl groups such as phenyl group; halogen atoms (fluorine, chlorine, bromine or iodine atom); hydroxyl group; C<sub>1-8</sub>alkoxy groups such as methoxy and ethoxy groups; carboxyl group; diaryl phosphoroxy groups such as diphenyl phosphoroxy group; cyano group; nitro group; and amino group. These substituents may be used singly or in combination.

20         The preferred substituent includes hydroxyl group, diaryl phosphoroxy group, and amino group. Incidentally,

there is no particular restriction on numbers of the substituent, and the number of substituent is for example about 0 to 4, preferably about 0 to 3, and more preferably about 0 to 2.

5 More concretely, as alkyl groups substituted with hydroxyl group, there may be, for example, hydroxymethyl group, hydroxyethyl group, 3-, 2-, or 1-hydroxy-n-propyl group, 1- or 2-hydroxyisopropyl group, hydroxy-t-butyl group, 1,2-dihydroxyethyl group, and 1,2- or 2,3-dihydroxy-n-propyl group, and preferably hydroxymethyl group and 1,2-dihydroxyethyl group.

As alkyl groups substituted with diaryl phosphoroxy group, there are exemplified diphenylphosphoroxyethyl group, dicresylphosphoroxyethyl group,

15 diphenylphosphoroxyethyl group, dicresylphosphoroxyethyl group, 3-, 2- or 1-diphenylphosphoroxy-n-propyl group, 3-, 2- or 1-dicresylphosphoroxy-n-propyl group, 1- or 2-diphenylphosphoroxyisopropyl group, 1- or 2-dicresylphosphoroxyisopropyl group, diphenylphosphoroxy-t-butyl group, dicresylphosphoroxy-t-butyl group, 1,2-bis(diphenylphosphoroxy)ethyl group, 1,2- or 2,3-bis(diphenylphosphoroxy)-n-propyl group, and 1,2- or 2,3-bis(dicresylphosphoroxy)-n-propyl group, and preferably 25 diphenylphosphoroxy methyl group and 1,2-bis(diphenylphosphoroxy)ethyl group.

As alkyl groups substituted with amino group, there

are exemplified aminomethyl group, aminoethyl group, 3-, 2-, or 1-amino-n-propyl group, 1- or 2-aminoisopropyl group, amino-t-butyl group, 1,2-diaminoethyl group, and 1,2- or 2,3-diamino-n-propyl group, and preferably 5 aminomethyl group and 1,2-diaminoethyl group.

As alkoxy groups, there may be mentioned, for example, C<sub>1-8</sub>alkoxy groups such as methoxy, ethoxy, n-propoxy, isopropoxy, isobutoxy, t-butoxy, t-pentyloxy, hexyloxy, isoctyloxy, t-octyloxy, and 2-ethylhexyloxy groups 10 (preferably C<sub>1-6</sub>alkoxy groups, more preferably C<sub>1-4</sub>alkoxy groups, and particularly methoxy, ethoxy, isopropoxy, and t-butoxy groups).

As alkenyl groups, there may be, for example, vinyl, acryl, methacryl, isobut enyl, styrenyl, 1,3-butadienyl, 15 and isoprenyl groups, and preferably vinyl group and methacryl group.

The aryl groups include, for example, C<sub>6-14</sub>aryl groups such as phenyl group and naphthyl group, preferably C<sub>6-10</sub>aryl groups, and more preferably phenyl group.

20 The aryl groups may have a substituent. As the substituent, there may be various substituents, for example, C<sub>1-8</sub>alkyl groups such as methyl and ethyl groups (preferably C<sub>1-6</sub>alkyl groups, and more preferably C<sub>1-4</sub>alkyl groups); C<sub>3-8</sub>cycloalkyl groups such as cyclohexyl group; 25 C<sub>6-18</sub>aryl groups such as phenyl group; C<sub>6-12</sub>aryl-C<sub>1-4</sub>alkyl groups such as benzyl group; halogen atoms (fluorine, chlorine, bromine or iodine atom); hydroxyl group; C<sub>1-</sub>

alkoxy groups such as methoxy and ethoxy groups (preferably C<sub>1-6</sub>alkoxy groups, and more preferably C<sub>1-4</sub>alkoxy groups); carboxyl group; C<sub>1-4</sub>alkoxycarbonyl groups such as methoxycarbonyl group; C<sub>1-4</sub>alkyl-carbonyl groups such as methylcarbonyl group; C<sub>6-12</sub>aryl-carbonyl groups; C<sub>1-6</sub>acyloxy groups such as acetyloxy group; cyano group; nitro group; and sulfonyl group. These substituents may be used singly or in combination.

The preferred substituent includes alkyl group, hydroxyl group, alkoxy group, and halogen atom, and particularly alkyl group or alkoxy group.

Incidentally, there is no particular restriction on numbers of the substituent, and the number of substituent is for example about 0 to 4, preferably about 0 to 3, and more preferably about 0 to 2. The position of the substituent on benzene ring may be 2-, 3- or 4-position, 2,6- or 3,5-position, or 2,4,6-position, etc.

More concretely, as aryl groups substituted (modified) with alkyl group, there are exemplified mono, di or tri-C<sub>1-6</sub>alkylphenyl groups such as o-, m- or p-toluyl group, o-, m- or p-ethylphenyl group, o-, m- or p-n-octylphenyl group, o-, m- or p-(1,1,3,3-tetramethylbutyl)phenyl group, o-, m- or p-t-butylphenyl group, 2,6-, 2,5-, 2,4-, 2,3-, 3,5- or 3,4-xylyl group, 2,4,6- or 3,4,5-trimethylphenyl group, 2,6-, 2,5-, 2,4-, 2,3-, 3,5- or 3,4-di-t-butylphenyl group, and 2-methyl-6-t-butylphenyl group; and mono, di or tri-C<sub>1-6</sub>

alkylnaphthyl groups such as 2- or 3-methyl-1-naphthyl group and 1-, 3- or 4-methyl-2-naphthyl group.

The preferred alkyl-substituted aryl group includes mono, di or tri-C<sub>1-4</sub>alkylphenyl groups such as o-, m- or p-tolyl group, p-ethylphenyl group, p-t-butyl group, p-(1,1-3,3-tetramethylbutyl)phenyl group, 2,4-, 3,4-, or 3,5-xylyl group, 2,4- or 2,6-di-t-butyl group, 2-methyl-6-t-butylphenyl group, and 2,4,6-trimethylphenyl group; and mono, di or tri-C<sub>1-4</sub>alkylnaphthyl groups such as 2-methyl-1-naphthyl group.

As phenyl groups substituted (modified) with alkoxy group, there are may be, for example, mono, di or tri-C<sub>1-6</sub>alkoxyphenyl groups such as o-, m- or p-methoxyphenyl group, o-, m- or p-ethoxyphenyl group, o-, m- or p-n-propoxyphenyl group, o-, m- or p-isopropoxyphenyl group, o-, m- or p-t-butoxyphenyl group, o-, m- or p-t-pentyloxyphenyl group, 2,3-, 2,4-, 2,5-, 2,6-, 3,4- or 3,5-dimethoxyphenyl group, 2,3-, 2,4-, 2,5-, 2,6-, 3,4- or 3,5-diethoxyphenyl group, 2,3-, 2,4-, 2,5-, 2,6-, 3,4- or 3,5-diisobutoxyphenyl group, 2,3-, 2,4-, 2,5-, 2,6-, 3,4- or 3,5-di-tertiary-butoxyphenyl group, 2,3,4-, 2,4,6-, 3,4,5-, 2,3,5- or 2,3,6-trimethoxyphenyl group, and 2,3,4-, 2,4,6-, 3,4,5-, 2,3,5- or 2,3,6-triethoxyphenyl group.

The preferred alkoxy-substituted aryl group includes mono, di or tri-C<sub>1-4</sub>alkoxyphenyl groups such as o-, m- or p-methoxyphenyl group, 2,6- or 3,5-

dimethoxyphenyl group, and 3,4,5- or 2,4,6-trimethoxyphenyl group.

The rings  $z^1$ ,  $z^2$  and  $z^3$  may be substituted (modified) with a substituent R. Aliphatic polycyclic hydrocarbon rings (particularly adamantane ring) substituted with the R (particularly alkyl group, alkoxy group, hydroxyl group, etc) includes the following rings.

Adamantane rings substituted with alkyl group [e.g.,  
mono, di or tri-C<sub>1-6</sub>alkyladamantane rings such as  
10 methyladamantane ring, ethyladamantane ring, n-  
propyladamantane ring, isopropyladamantane ring,  
dimethyladamantane ring, diethyladamantane ring,  
trimethyladamantane ring, and triethyladamantane ring  
(preferably mono or di-C<sub>1-4</sub>alkyladamantane rings such as  
15 methyladamantane ring, dimethyladamantane ring, and  
diethyladamantane ring)].

Adamantane rings substituted with alkoxy group [e.g.,  
mono, di or tri-C<sub>1-6</sub>alkoxyadamantane rings such as  
methoxyadamantane ring, isobutoxyadamantane ring, n-  
propoxyadamantane ring, isopropoxy adamantane ring,  
dimethoxy adamantane ring, and diisobutoxy adamantane ring  
(preferably mono or di-C<sub>1-4</sub>alkoxyadamantane rings such as  
dimethoxyadamantane ring and diisobutoxy adamantane  
ring)].

25 Adamantane rings substituted with hydroxyl group  
[e.g., mono, di or tri-hydroxyadamantane rings such as 2-  
or 3-hydroxyadamantane ring, 2,4- or 3,5-

dihydroxyadamantane ring, and 3,5,7-trihydroxyadamantane ring (preferably di or tri-hydroxyadamantane rings such as 2- or 3-hydroxyadamantane ring, 3,5-dihydroxy adamantane ring, and 3,5,7-trihydroxyadamantane ring)].

5        As aromatic hydrocarbon rings (particularly benzene ring) substituted with the group R, there are exemplified substituted benzene rings corresponding to the above substituted phenyl group (e.g., mono, di or tri-C<sub>1</sub>-alkylbenzene rings, mono, di or tri-C<sub>1-4</sub>alkoxybenzene 10 rings).

The preferred rings Z<sup>1</sup>, Z<sup>2</sup> and Z<sup>3</sup> are aliphatic dicyclic or tricyclic hydrocarbon rings such as norbornane ring or adamantane ring, which may have a substituent (e.g., hydroxyl group, halogen atom, C<sub>1-8</sub>alkyl groups, C<sub>1-8</sub>alkoxy groups), or benzene ring which may have the substituent. 15 Moreover, the preferred rings Z<sup>1</sup>, Z<sup>2</sup> and Z<sup>3</sup> may be C<sub>6-12</sub>cycloalkane ring such as cyclohexane ring which may have a substituent (e.g., hydroxyl group, halogen atom, C<sub>1-8</sub>alkyl groups, C<sub>1-8</sub>alkoxy groups), or C<sub>6-12</sub>cycloalkene rings 20 such as cyclohexene ring which may have the substituent.

A represents polyvalent groups corresponding to alkanes (e.g., C<sub>1-6</sub>alkanes such as methane, ethane, propane and butane, preferably C<sub>1-4</sub>alkanes, and more preferably C<sub>1-2</sub>alkanes), and usually represents divalent or trivalent 25 groups. Incidentally, a bonding position of the polyvalent group may be at or on any carbon atom of the alkane.

Concerning to  $-NR^1-$  represented by  $Y^1$ ,  $Y^2$  and  $Y^3$ , as alkyl groups represented by the  $R^1$ , there are exemplified the above exemplified alkyl groups (e.g.,  $C_{1-6}$ alkyl groups such as methyl, ethyl, propyl, and butyl groups, preferably 5  $C_{1-4}$ alkyl groups, particularly methyl group or ethyl group). As the  $-NR^1-$  group, there are exemplified  $-N(CH_3)-$  and  $-N(C_2H_5)-$ . The preferred  $Y^1$ ,  $Y^2$  and  $Y^3$  represent  $-O-$  or  $-N(R^1)-$ , and particularly  $-O-$ .

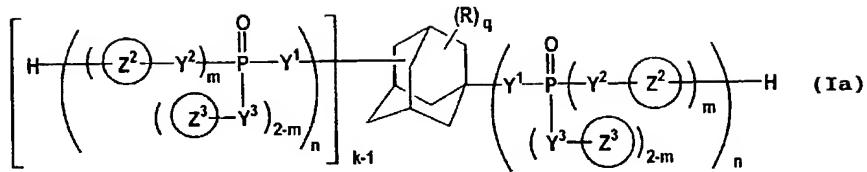
$k$  is an integer of 1 to 6, and  $k$  may be different 10 each other depending on the species of the ring  $Z$ .  $k$  is usually 1 to 3.  $n$  is an integer of not less than 1 (e.g., 1 to 5, preferably 1 to 3, and more preferably 1 to 2), and is usually 1.  $q$  is an integer of 0 to 5, usually about 0 to 3, and preferably about 0 to 2.  $s$  is an integer of 15 1 to 4, and is usually 2 to 4 when  $k$  is 1, and at least one of plural factors is 2 to 4 when  $k$  is 2 to 6.

Incidentally, species of units comprising the group 20  $A$  and the group  $Z^2$  and/or  $Z^3$  which are units corresponding to  $k$  may be different depending on the number of  $k$ . Moreover, each kind of units comprising the group  $Y^1$  and phosphorus atom which are units corresponding to  $n$  or  $s$  may be different depending on the number of  $n$  or  $s$ . Further, kinds of  $R$  and  $A$  may be respectively different depending on the numbers of  $q$  and  $r$ .

25 Among phosphorus-containing compounds represented by the formula (I), (II) or (III), as typical compounds, there are exemplified (i) a phosphorus-containing compound

in which, in the formula (I),  $Z^1$  is adamantane ring,  $k$  is not less than 2, and  $r$  (the factor or coefficient for A) is 0 [a compound represented by the formula (Ia)]; (ii) a phosphorus-containing compound in which  $Z^1$  is adamantane ring,  $k$  is 1, and  $r$  is 0 in the formula (I) [a compound represented by the formula (Ib)]; (iii) a phosphorus-containing compound in which, in the formula (I),  $Z^1$  is tricyclo[5.2.1.0<sup>2,6</sup>] decane ring,  $k$  is 2,  $n$  and  $r$  are 1, and A is methylene group [a compound represented by the formula (Ic)]; (iv) a phosphorus-containing compound in which  $Z^1$  is benzene ring,  $r$  is 1, and A is methylene group [a compound represented by the formula (Id)]; (v) a phosphorus-containing compound in which, in the formula (I) or (II),  $Z^1$  is a saturated alicyclic hydrocarbon ring such as cyclohexane ring and norbornane ring, or an unsaturated alicyclic hydrocarbon ring such as cyclohexene ring [a compound represented by the formula (Ie) or (IIa)]; (vi) a phosphorus-containing compound in which, in the formula (Ie),  $Z^1$  is cyclohexane ring,  $k$  is 2, one of  $r$  is 1, and A is methylene group [a compound represented by the formula (If)]; and (vii) a phosphorus-containing compound in which  $Z^1$  is adamantane ring in the formula (III) [a compound represented by the formula (IIIa)].

(i) Phosphorus-containing compounds represented by the formula (Ia):



wherein  $z^2$ ,  $z^3$ , R,  $y^1$ ,  $y^2$ ,  $y^3$ , k, m, n and q have the same meanings as defined above.

In the formula (Ia), exemplified as the preferred ring  $z^2$  and  $z^3$  is a benzene ring or an adamantane ring. As the preferred R, there are exemplified hydrogen atom, halogen atom, hydroxyl group,  $C_{1-6}$ alkyl group or  $C_{1-6}$ alkoxy group (particularly hydrogen atom or  $C_{1-4}$ alkyl group). The preferred group  $y^1$ ,  $y^2$  and  $y^3$  are -O- or  $-NR^1-$  ( $R^1$  has the same meaning as defined above). Moreover, k is usually 2 to 4, and n is 1 to 3 (particularly 1). The ring  $z^2$  and  $z^3$  may have a substituent (e.g., the group R).

Among the compound represented by the formula (Ia), as typical compounds, there are exemplified the following compounds.

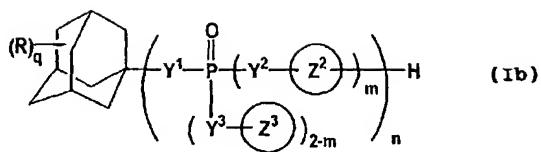
A phosphorus-containing compound in which the ring  $z^2$  and  $z^3$  each is a benzene ring which may have a substituent (e.g.,  $C_{1-4}$ alkyl group, hydroxyl group), R is  $C_{1-4}$ alkyl group, the groups  $y^1$  to  $y^3$  are -O-, k is 2 to 4, n is 1, and q is 0 to 2 [e.g., adamantylbis, tris or tetrakis-(di $C_{6-10}$ arylphosphate) such as adamantylbis(diphenylphosphate) [or adamantane-diyl-bis(diphenylphosphate)], adamantyltris(diphenylphosphate), adamantyl

tetrakis(diphenylphosphate), dimethyladamantylbis(diphenylphosphate), adamantylbis(dicresylphosphate), adamantyltris(dicresylphosphate), adamantyltetrakis(dicresylphosphate), and dimethyladamantylbis(dicresylphosphate)].

A phosphorus-containing compound in which the ring  $z^2$  and  $z^3$  each is a benzene ring which may have a substituent (e.g., C<sub>1-4</sub>alkyl group, hydroxyl group), R is C<sub>1-4</sub>alkyl group, the groups Y<sup>1</sup> to Y<sup>3</sup> are -NR<sup>1</sup>- (R<sup>1</sup> is hydrogen atom), k is 2 to 4, n is 1, and q is 0 to 2 [adamantylbis, tris or tetrakis-(diC<sub>6-10</sub>arylphosphoramide) such as adamantylbis(diphenyl phosphoramide) [or adamantane-diyl-bis(diphenyl phosphinoylamino)], adamantyltris(diphenylphosphoramide), adamantyltetrakis(diphenylphosphoramide), dimethyladamantylbis(diphenylphosphoramide), adamantylbis(dicresylphosphoramide), adamantyltris (dicresylphosphoramide), adamantyltetrakis(dicresyl phosphoramide), and dimethyladamantylbis (dicresyl phosphoramide)].

Particularly, as the preferred compound, there are exemplified adamantylbis(diphenylphosphate), dimethyl adamantylbis(diphenylphosphate), and adamantyltris (diphenylphosphate).

(ii) Compounds represented by the following formula  
25 (Ib)



wherein  $Z^2$ ,  $Z^3$ ,  $R$ ,  $Y^1$ ,  $Y^2$ ,  $Y^3$ ,  $m$ ,  $n$  and  $q$  have the same meanings as defined above.

5        In the formula (Ib), exemplified as the preferred ring  $Z^2$  and  $Z^3$  each is a benzene ring or an adamantane ring. As the preferred  $R$ , there are exemplified hydrogen atom, halogen atom, hydroxyl group,  $C_{1-6}$ alkyl group or  $C_{1-6}$ alkoxy group (particularly hydrogen atom, hydroxyl group,  $C_{1-4}$ alkyl group or  $C_{1-4}$ alkoxy group), and the preferred groups  $Y^1$ ,  $Y^2$  and  $Y^3$  each is  $-O-$  or  $-NR^1-$ .

10      Among the compounds represented by the formula (Ib), as typical compounds, there are exemplified the following compounds.

15      A phosphorus-containing compound in which the ring  $Z^2$  and  $Z^3$  each is a benzene ring or an adamantane ring which may have a substituent (e.g.,  $C_{1-4}$ alkyl group),  $R$  is  $C_{1-4}$ alkyl group, the groups  $Y^1$  to  $Y^3$  are  $-O-$ ,  $k$ ,  $m$  and  $n$  are 1, and  $q$  is 0 to 3 [e.g., adamantyldi $C_{6-10}$ arylphosphates such as adamantyldiphenylphosphate and (dimethyladamantyl)diphenylphosphate, bis(adamantyl) $C_{6-10}$ arylphosphates such as bis(adamantyl)phenylphosphate and bis(dimethyladamantyl)phenylphosphate, triadamantylphosphates such as tris(adamantyl)phosphate

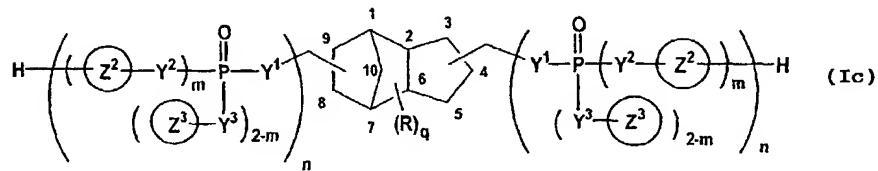
and tris(dimethyladamantyl)phosphate].

A phosphorus-containing compound in which the ring  $Z^2$  and  $Z^3$  each is a benzene ring or an adamantane ring which may have a substituent (e.g.,  $C_{1-4}$ alkyl group), R is  $C_{1-4}$ alkyl group, the groups  $Y^1$  to  $Y^3$  are  $-NR^1-$  ( $R^1$  is hydrogen atom), k, m and n are 1, and q is 0 to 2 [e.g., 5 adamantyldi $C_{6-10}$ arylphosphoramides such as adamantyl diphenylphosphoramides and dimethyladamantyldiphenyl phosphoramides, bis(adamantyl) $C_{6-10}$ arylphosphoramides 10 such as bis(adamantyl)phenylphosphoramides, bis(dimethyladamantyl)phenylphosphoramides, trisadamantylphosphoramides, tris(dimethyladamantyl) phosphoramides].

Particularly, adamantyldiphenylphosphate, 15 dimethyladamantyldiphenylphosphate, and bis(adamantyl)phenylphosphate are preferred.

Incidentally, the compound of the formula (Ib) corresponds to a compound in which k is 1 in the formula (Ia).

20 (iii) Compounds represented by the following formula (Ic):



wherein  $Z^2$ ,  $Z^3$ , R,  $Y^1$ ,  $Y^2$ ,  $Y^3$ , m, n and q have the same meanings as defined above.

In the formula (Ic), the preferred ring  $Z^2$  and  $Z^3$  each is a benzene ring, and the preferred R is halogen atom, hydroxyl group,  $C_{1-6}$ alkyl group or  $C_{1-6}$ alkoxy group. Moreover, the preferred groups  $Y^1$ ,  $Y^2$  and  $Y^3$  are -O-.

5 Among the compound represented by the formula (Ic), as typical compounds, there are exemplified phosphorus-containing compounds in which the ring  $Z^2$  and  $Z^3$  each is a benzene ring which may have a substituent (e.g.,  $C_{1-4}$ alkyl group, hydroxyl group), and the groups  $Y^1$   $Y^2$  and  $Y^3$  are -O- [e.g., bis[(di $C_{6-10}$ arylphosphoroxy) methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane such as 3,8-, 3,9-, 4,8- or 4,9-bis[(diphenylphosphoroxy)methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane, 3,8-, 3,9-, 4,8- or 4,9-bis[(dixylylphosphoroxy)methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane, 3,8-, 3,9-, 4,8- or 4,9-bis[(ditoluylphosphoroxy)methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane, and 3,8-, 3,9-, 4,8- or 4,9-bis[(di Cresylphosphoroxy)methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane].

As the preferred compound, there is exemplified 3,8-, 3,9-, 4,8- or 4,9-bis[(diphenylphosphoroxy)methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane.

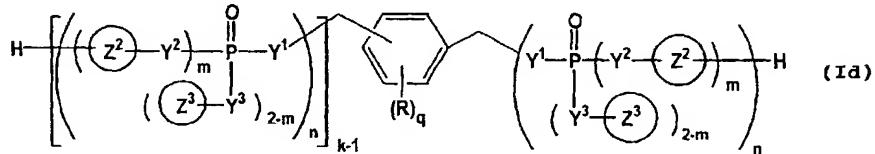
Moreover, the compound represented by the formula (Ic) includes isomers different in the position of substituents and the configuration. For example, explaining 3,8-, 3,9-, 4,8- or 4,9-bis[(diphenylphosphoroxy)methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane for example, the isomers include (4R,8S)-bis(diphenyl

phosphoroxyethyl)-(1R,2S,6R,7R)-tricyclo[5.2.1.0<sup>2,6</sup>]decane, (3R,8R)-bis(diphenylphosphoroxyethyl)-(1R,2S,6S,7R)-tricyclo[5.2.1.0<sup>2,6</sup>]decane, (3S,9R)-bis(diphenylphosphoroxyethyl)-(1S,2R,6R,7S)-tricyclo[5.2.1.0<sup>2,6</sup>]decane, (3S,9S)-bis(diphenylphosphoroxyethyl)-(1S,2R,6R,7S)-tricyclo[5.2.1.0<sup>2,6</sup>]decane, (3S,9R)-bis(diphenylphosphoroxyethyl)-(1R,2R,6R,7S)-tricyclo[5.2.1.0<sup>2,6</sup>]decane, (4S,8S)-bis(diphenylphosphoroxyethyl)-(1S,2S,6S,7R)-tricyclo[5.2.1.0<sup>2,6</sup>]decane, etc.

The phosphorus-containing compound of the present invention may be a sole compound or a mixture of structural isomers, and may include the above mentioned stereoisomer.

Among the compound represented by the formula (Ic), as the preferred compound, there is exemplified 3,8-, 3,9-, 4,8- or 4,9-bis[(diphenylphosphoroxy)methyl]tricyclo[5.2.1.0<sup>2,6</sup>]decane. Moreover, as the stereoisomer of these compounds, there is exemplified (4R,8S)-bis(diphenylphosphoroxyethyl)-(1R,2S,6R,7R)-tricyclo[5.2.1.0<sup>2,6</sup>]decane.

(iv) Compounds represented by the formula (Id):



wherein  $z^2$ ,  $z^3$ ,  $Y^1$ ,  $Y^2$ ,  $Y^3$ ,  $k$ ,  $m$ ,  $n$  and  $q$  have the same meanings as defined above.

In the formula (Id), the preferred ring  $Z^2$  and  $Z^3$  are benzene rings, and the preferred groups  $Y^1$ ,  $Y^2$  and  $Y^3$  are -O-.

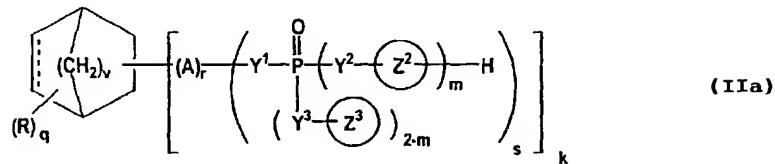
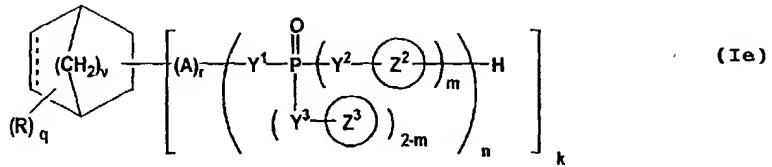
Among the compounds represented by the formula (Id), 5 as typical compounds, there are exemplified the following compounds.

A phosphorus-containing compound in which the ring  $Z^2$  and  $Z^3$  are phenyl groups, the groups  $Y^1$ ,  $Y^2$  and  $Y^3$  are -O-, and  $m$  is 1 [e.g., xylyleneglycolbis(diphenyl phosphate) such as o-, m- or p-xylyleneglycolbis(diphenyl phosphate)].

A phosphorus-containing compound in which the ring  $Z^2$  and  $Z^3$  each is a benzene ring having a substituent ( $C_{1-4}$ alkyl group), the groups  $Y^1$ ,  $Y^2$  and  $Y^3$  are -O- and  $m$  is 1 [e.g., xylyleneglycolbis(dicresylphosphate) such as o-, m- or p-xylyleneglycolbis(dicresylphosphate), xylyleneglycolbis(dimethylphenylphosphate) such as o-, m- or p-xylyleneglycolbis(2,4-dimethylphenylphosphate), o-, m- or p-xylyleneglycolbis(2,6-dimethylphenylphosphate), 20 and o-, m- or p-xylyleneglycolbis(3,5-dimethylphenyl phosphate)].

Particularly, xylyleneglycolbis(diphenyl phosphate) is preferred.

(v) Compounds represented by the formula (Ie) or 25 (IIa):



wherein the following structure

— — —

represents single bond or double bond; v represents an integer of 0 to 2; and the  $Z^2$ ,  $Z^3$ , R,  $Y^1$ ,  $Y^2$ ,  $Y^3$ , m, n,

5 k, q, r and s have the same meanings as defined above.

In the formulae (Ie) and (IIa), the preferred rings  $Z^2$  and  $Z^3$  are benzene rings, and the preferred R is halogen atom, hydroxyl group,  $C_{1-6}$ alkyl group which may have a substituent, and  $C_{1-6}$ alkoxy group. Moreover, the preferred groups  $Y^1$ ,  $Y^2$  and  $Y^3$  are -O-.

10 Among compounds represented by the formula (Ie), as typical compounds, there are exemplified phosphorus-containing compounds in which the ring  $Z^2$  and  $Z^3$  each is a benzene ring which may have a substituent (e.g.,  $C_{1-4}$ alkyl group, hydroxyl group), and the groups  $Y^1$ ,  $Y^2$  and  $Y^3$  are -O- (e.g., bis, tris or tetrakis-(diphenyl phosphoroxy)norbornanes such as 2,3-bis(diphenyl phosphoroxy)norbornane and 2,3,5,6-tetrakis(diphenyl

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phosphoroxy)norbornane; bis, tris or tetrakis-(diphenyl phosphoroxyC<sub>1-4</sub>alkyl)norbornanes such as 2,5-bis(diphenylphosphoroxyethyl)norbornane and 2,3,5,6-tetrakis(diphenylphosphoroxyethyl)norbornane;

5 bis(diphenylphosphoroxy)C<sub>2-4</sub>alkenylcyclohexanes such as 1,2-bis(diphenylphosphoroxy)-4-vinylcyclohexane; (diphenylphosphoroxyC<sub>1-4</sub>alkyl)cyclohexenes such as 1-diphenylphosphoroxyethyl-3-cyclohexene; mono, di or tri-C<sub>1-4</sub>alkyl(diphenylphosphoroxyC<sub>1-4</sub>alkyl)cyclohexyl

10 phosphates such as 3,3-dimethyl-5-(diphenylphosphoroxy methyl)cyclohexylphosphate].

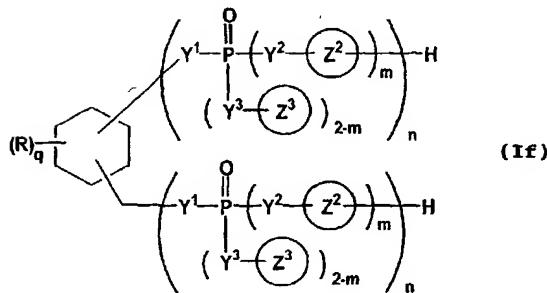
Moreover, among the compounds represented by the formula (IIa), as typical compounds, there is exemplified a phosphorus-containing compounds in which the ring Z<sup>2</sup> and Z<sup>3</sup> each is a benzene ring which may have a substituent (e.g., C<sub>1-4</sub>alkyl group, hydroxyl group), Y<sup>1</sup>, Y<sup>2</sup> and Y<sup>3</sup> are -O-, k is 2 to 6, at least one of s is 2 to 4, and A corresponding to the factor (coefficient) s is C<sub>1-4</sub>alkylene group [e.g., bis(diphenylphosphoroxy)-{bis(diphenyl phosphoroxy)C<sub>1-4</sub>alkyl}cyclohexane such as 1,2-bis(diphenylphosphoroxy)-4-[1',2'-bis(diphenyl phosphoroxy)ethyl]cyclohexane].

As the preferred compound, there are exemplified 2,5-bis(diphenylphosphoroxyethyl)norbornane, 2,3-bis(diphenylphosphoroxy)norbornane, 1,2-bis(diphenyl phosphoroxy)-4-vinylcyclohexane, 3,3-dimethyl-5-(diphenylphosphoroxyethyl)cyclohexylphosphate, 1,2-

bis(diphenylphosphoroxy)-4-[1',2'-bis(diphenyl phosphoroxy)ethyl]cyclohexane, and 1-diphenylphosphoroxy methyl-3-cyclohexene.

(23/21)

5 (vi) Compounds represented by the formula (If):



wherein R, Y<sup>1</sup>, Y<sup>2</sup>, Y<sup>3</sup>, Z<sup>2</sup>, Z<sup>3</sup>, m, n and q have the same meanings as defined above.

10 The formula (If) corresponds to a phosphorus-containing compound wherein k is 2, one of r is 1, and v is 0 in the formula (Ie).

In the formula (If), the preferred rings Z<sup>2</sup> and Z<sup>3</sup> each is a benzene ring, and the preferred R is halogen atom, 15 hydroxyl group, C<sub>1-6</sub>alkyl group or C<sub>1-6</sub>alkoxy group. Moreover, the preferred groups Y<sup>1</sup>, Y<sup>2</sup> and Y<sup>3</sup> each is a -O- or -NR<sup>1</sup>-.

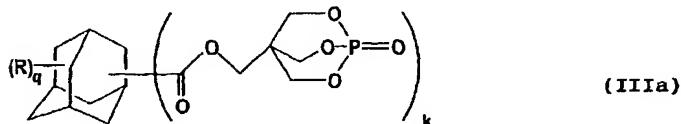
20 Among compounds represented by the formula (If), as typical compounds, there are exemplified the following compounds.

A phosphorus-containing compounds in which the rings

z<sup>2</sup> and z<sup>3</sup> each is a benzene ring which may have a substituent (e.g., C<sub>1-4</sub>alkyl group, hydroxyl group), and the groups Y<sup>1</sup>, Y<sup>2</sup> and Y<sup>3</sup> are -O- [e.g., 1-diphenylphosphoroxy-3-diphenylphosphoroxyethyl cyclohexane, 3,3-dimethyl-5-(diphenylphosphoroxyethyl) cyclohexylphosphate].

A phosphorus-containing compounds in which the ring z<sup>2</sup> and z<sup>3</sup> each is a benzene ring which may have a substituent (e.g., C<sub>1-4</sub>alkyl group, hydroxyl group), and the groups Y<sup>1</sup>, Y<sup>2</sup> and Y<sup>3</sup> are -NR<sup>1</sup>- [e.g., 1-diphenyl phosphorylamino-3-diphenylphosphorylaminoethyl cyclohexane, 3,3-dimethyl-5-(diphenylphosphorylaminoethyl) cyclohexylphosphoramido].

(vii) Compounds represented by the formula (IIIA):



wherein R, q and k have the same meanings as defined above.

In the formula (IIIA), the preferred R is hydrogen atom, carboxyl group, halocarboxyl group, or C<sub>1-4</sub>alkyl group.

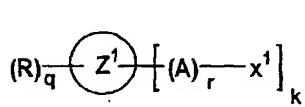
Among the compounds represented by the formula (IIIA), as typical compounds, there are exemplified a phosphorus-containing compounds in which R is C<sub>1-4</sub>alkyl group, and k is 1 to 4 [e.g., (1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl adamantane

carbonate, bis(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl adamantanedicarbonate, (1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl dimethyladamantanecarbonate, bis(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl dimethyladamantanedicarbonate, tris(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl adamantanetricarbonate, and tetrakis(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl adamantanetetracarbonate].

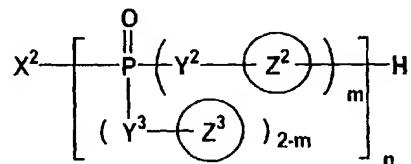
[Production Process]

The phosphorus-containing compound (I), (II) or (III) of the present invention can be prepared by reacting a compound represented by the following formula (I-1), (II-1) or (III-1) and a phosphorus compound represented by the following formula (I-2), (II-2) or (III-3).

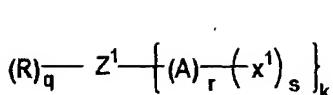
Such process gives a high-purity phosphorus-containing compound with high yield by simple manner.



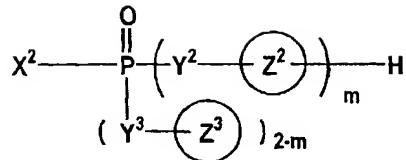
(I-1)



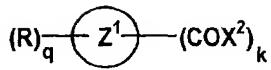
(I-2)



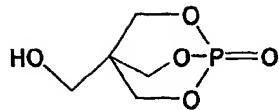
(II-1)



(II-2)



(III-1)



(III-2)

wherein  $X^1$  represents hydroxyl group, thiol group,

amino group or substituted amino group;  $X^2$  represents

5 halogen atom, hydroxyl group, or alkoxy group;  $Z^1$ ,  $Z^2$ ,  $Z^3$ ,  
R,  $Y^1$ ,  $Y^2$ ,  $Y^3$ , k, m, q, r and s have the same meanings as  
defined above.

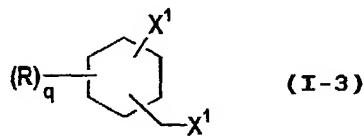
As the substituted amino group represented by  $X^1$ ,  
there are exemplified alkyl-substituted amino groups (e.g.,  
10 mono or diC<sub>1-4</sub>alkylamino groups such as methylamino,  
ethylamino, dimethylamino, diethylamino, and  
methylethylamino groups).

As the halogen atom represented by  $X^2$ , there are  
exemplified fluorine, chlorine, bromine, and iodine atoms  
15 (particularly chlorine atom). As the alkoxy group, there  
are exemplified the above exemplified C<sub>1-8</sub>alkoxy groups  
(particularly C<sub>1-4</sub>alkoxy groups such as methoxy and ethoxy

groups) and C<sub>6-10</sub>aryloxy groups such as phenoxy group.

Moreover, the compound represented by the formula (I-1) mentioned above includes a compound represented by the following formula (I-3):

5



wherein R, X<sup>1</sup> and q have the same meanings as defined above.

More concretely, as the compound represented by the 10 formula (I-1), the following compounds are exemplified.

(1) A compound in which the X<sup>1</sup> is hydroxyl group, for example,

a compound in which the ring Z<sup>1</sup> is adamantine ring which may have a substituent (e.g., alkyl group, alkoxy group) [adamantanemonoools which may have a substituent such as adamantanol, dimethyladamantanol, diethyladamantanol, and dimethoxyadamantanol; adamantanediools which may have a substituent such as adamantanediol, dimethyladamantanediol, and 20 diethyladamantanediol; adamantanetriol, adamantanetetraol];

a compound in which the ring Z<sup>1</sup> is tricyclo[5.2.1.0<sup>2,6</sup>]decane ring [1(R),2(S),6(S),7(R)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-3(R),8(R)-dimethanol.

1(S),2(R),6(R),7(S)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-  
3(S),9(R)-dimethanol, 1(S),2(R),6(R),7(S)-  
[5.2.1.0<sup>2,6</sup>]tricyclodecane-3(S),9(S)-dimethanol,  
1(R),2(R),6(R),7(S)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-  
5 3(S),9(R)-dimethanol, 1(S),2(S),6(S),7(R)-  
[5.2.1.0<sup>2,6</sup>]tricyclodecane-4(S),8(S)-dimethanol];  
a compound in which the ring Z<sup>1</sup> is benzene ring (e.g.,  
o-xylyleneglycol, m-xylyleneglycol, p-xylyleneglycol);  
a compound in which the ring Z<sup>1</sup> is cyclohexane ring  
10 or norbornane ring having a substituent [e.g., 4-  
vinylcyclohexane-1,2-diol, 4-(1,2'-  
dihydroxyethyl)cyclohexane-1,2-diol,  
norbornanediethanol, norbornane-2,5-diol, 3-  
cyclohexenemethanol, 3-hydroxymethyl-5,5-  
15 dimethylcyclohexanol].

(2) A compound in which X<sup>1</sup> is thiol group, for example,  
a compound having adamantine ring which may have a  
substituent as the ring Z<sup>1</sup> (e.g., adamantanethiol).

(3) A compound in which the X<sup>1</sup> is amino group or  
20 N-substituted amino group, for example, a compound having  
adamantine ring which may have a substituent as the ring  
Z<sup>1</sup> [e.g., aminoadamantine, N-C<sub>1-4</sub>alkylaminoadamantine  
(N-methylaminoadamantine), dimethyladamantaneamine,  
diaminoadamantine, dimethyladamantanediamine,  
25 triaminoadamantine, tetraaminoadamantine].

Among the compounds represented by the formula (I-1),  
(i) a useful compound for preparing the compound of the

formula (Ia) includes adamantanediol, dimethyladamantanediol, and adamantanetriol.

(ii) As a useful compound for preparing the compound of the formula (Ib), there are exemplified adamantanol, 5 dimethyladamantanol, adamantanediol, dimethyladamantanediol, adamantanetriol, and adamantaneamine.

(iii) As a useful compound for preparing the compound of the formula (Ic), there are exemplified 10 1(R),2(S),6(S),7(R)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-3(R),8(R)-dimethanol, 1(S),2(R),6(R),7(S)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-3(S),9(R)-dimethanol, 1(S),2(R),6(R),7(S)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-3(S),9(S)-dimethanol, 1(R),2(R),6(R),7(S)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-3(S),9(R)-dimethanol, and 15 1(S),2(S),6(S),7(R)-[5.2.1.0<sup>2,6</sup>]tricyclodecane-4(S),8(S)-dimethanol. When these compounds are used as raw materials, these compounds may be a mixture of structural isomers, and may be a sole compound. Moreover, 20 these compounds may include a stereoisomer of the compound.

(iv) A useful compound for preparing the compound of the formula (Id) includes xylyleneglycols (o-, m- or p-xylyleneglycol).

(v) As a useful compound for preparing the compound 25 of the formula (Ie), there may be exemplified norbornanenedimethanol, 2,3-dihydroxynorbornane, 1,2-dihydroxy-4-vinylcyclohexane, 1,2-dihydroxy-4-(1',2'-

dihydroxyethyl)cyclohexane, 3-cyclohexen-1-methanol, and 3-hydroxymethyl-5,5-dimethylcyclohexanol.

(vi) A compound useful for preparing the compound of the formula (If) includes the compounds represented by 5 the formula (I-3) [e.g., 3-hydroxymethylcyclohexanol, 3-hydroxymethyl-5,5-dimethylcyclohexanol, 3-aminomethylcyclohexaneamine, and 3-aminomethyl-5,5-dimethylcyclohexaneamine].

As a compound represented by the formula (I-2), the 10 following compounds may be exemplified.

A compound in which the  $X^2$  is halogen atom [e.g., diC<sub>6-10</sub>arylphosphoric halides such as diphenylphosphoric chloride, ditoluylphosphoric chloride, dixylylphosphoric chloride, and dicresylphosphoric chloride; 15 bis(tricycloC<sub>8-12</sub>alkyloxy)phosphoric halides such as bis(adamantyloxy)phosphoric chloride; tricycloC<sub>8-12</sub>alkyloxyC<sub>6-10</sub>arylphosphoric halides such as adamantyloxyphenylphosphoric chloride].

A compound in which the  $X^2$  is hydroxyl group [e.g., 20 diC<sub>6-10</sub>arylphosphates such as diphenylphosphoric ester (diphenylphosphate), ditoluylphosphoric ester (ditoluylphosphate), dixylylphosphoric ester (dixylylphosphate), and dicresylphosphoric ester (dicresylphosphate); tricycloC<sub>8-12</sub>alkyl-C<sub>6-10</sub>arylphosphates such as adamantylphenylphosphoric ester; 25 bis(tricycloC<sub>8-12</sub>alkyl)phosphates such as bisadamantylphosphoric ester].

A compound in which the  $X^2$  is alkoxy group [e.g., triC<sub>6-10</sub>arylphosphates such as triphenylphosphate (TPP) and tricresylphosphate; monoC<sub>1-4</sub>alkyl-diC<sub>6-10</sub>arylphosphates such as methyldiphenylphosphate and 5 ethyldiphenylphosphate; tricycloC<sub>8-12</sub>alkyl-diC<sub>6-10</sub>arylphosphates such as diphenyladamantylphosphate].

Incidentally, as the compounds of the formula (I-2), commercially available products may be used, and may be prepared by reacting a phosphorus compound having 1 to 3 10 of the group  $X^2$  (e.g., phosphorus oxychloride, phenylphosphoric dichloride, phenylphosphoric acid) with alcohols having the ring  $Z^2$  and/or  $Z^3$  (e.g., adamantanol), thiols (adamantane thiol), or amines (aminoadamantane).

Among the compounds of the formula (I-2), as a useful 15 compound for preparing (i) the compound of the formula (Ia), (ii) the compound of the formula (Ib), (iii) the compound of the formula (Ic), (vi) the compound of the formula (Id), or (v) the compound of the formula (Ie), there may be exemplified diC<sub>6-12</sub>arylphosphoric chlorides such as 20 diphenylphosphoric chloride; diC<sub>6-12</sub>arylphosphates such as diphenylphosphoric acid; and TPP. Moreover, phosphorus oxychloride, phenylphosphoric dichloride, phenylphosphoric acid, etc may be used.

The compound represented by the formula (II-1) 25 includes, for example, a compound in which  $X^1$  is hydroxyl group [e.g., (mono or di-hydroxyC<sub>1-4</sub>alkyl)C<sub>4-10</sub>cycloalkanes such as (1,2-dihydroxyethyl)cyclohexane

and 1,2-dihydroxy-4-(1,2-dihydroxyethyl)cyclohexane].

The compound represented by the formula (II-2) corresponds to a compound in which  $n$  is 1 in the formula (I-2).

5        The compound represented by the formula (III-1) includes, for example, the following compounds.

A compound having halogen atom as  $X^2$  and adamantane ring as the ring  $Z^1$ , for example, a compound in which  $k$  is 1 [e.g., adamantanecarboxylic chloride, dimethyl 10 adamantanecarboxylic chloride, diethyladamantane carboxylic chloride, adamantanecarboxylic bromide, dimethyladamantanecarboxylic bromide, diethyladamantane carboxylic bromide]; a compound in which  $k$  is 2 [e.g., adamantanedicarboxylic dichloride, dimethyladamantane 15 dicarboxylic dichloride, diethyladamantanedicarboxylic dichloride, adamantanedicarboxylic dibromide, dimethyl adamantanedicarboxylic dibromide, diethyladamantane dicarboxylic dibromide]; a compound in which  $k$  is 3 [e.g., adamantanetricarboxylic trichloride, adamantane 20 tricarboxylic tribromide]; a compound in which  $k$  is 4 [e.g., adamantanetetracarboxylic tetrachloride, adamantane tetracarboxylic tetrabromide].

A compound having hydroxyl group as  $X^2$  and adamantane ring as the ring  $Z^1$ , for example, a compound in which  $k$  25 is 1 [e.g., adamantanecarboxylic acid, dimethyladamantane carboxylic acid, diethyladamantanecarboxylic acid]; a compound in which  $k$  is 2 [e.g., adamantanedicarboxylic acid,

dimethyladamantanedicarboxylic acid, diethyladamantane dicarboxylic acid]; a compound in which  $k$  is 3 [e.g., adamantanetricarboxylic acid]; a compound in which  $k$  is 4 [e.g., adamantanetetracarboxylic acid].

5 Among the compounds represented by the formula (III-1), as a useful compound for preparing (vii) the compound of the formula (IIIA), there are exemplified adamantanecarboxylic chloride, adamantanecarboxylic acid, adamantanedicarboxylic chloride, adamantanedicarboxylic dichloride.

10 The amount of the phosphorus compound of the formula (I-2) or (II-2) can be selected within the wide range according to the object compound, relative to 1 mol of the  $X^1$  group of the compound of the formula (I-1) (or the formula (I-3)) or (II-2), for example, within the range of about 15 0.1 to 50 mol, preferably about 0.3 to 30 mol, and more preferably about 0.5 to 10 mol.

15 More concretely, (i) in the case where the phosphorus-containing compound of the formula (Ia) is prepared, the amount of the phosphorus compound (I-2) is, for example, about 0.1 to 50 mol relative to 1 mol of the compound (I-1) having one  $X^1$  group, and is about 0.5 to 100 mol relative to 1 mol of the compound (I-1) having two  $X^1$  groups. Further, the amount of the phosphorus compound of the formula (I-2) is about 0.5 to 150 mol relative to 25 1 mol of the compound (I-1) having three  $X^1$  groups, and is about 0.5 to 200 mol relative to 1 mol of the compound

(I-1) having four  $X^1$  groups.

(ii) In the production of the phosphorus-containing compound of the formula (Ib), the amount of the phosphorus compound (I-2) is, for example, about 0.1 to 20 mol, 5 preferably about 0.2 to 10 mol, more preferably about 1.5 to 5.0 mol, and particularly about 1.5 to 2.5 mol, relative to 1 mol of the compound (I-1) having one  $X^1$  group.

(iii) In the production of the phosphorus-containing compound of the formula (Ic), the amount of the phosphorus compound (I-2) is, for example, about 0.1 to 20 mol, 10 preferably about 0.2 to 10 mol, about 1.0 to 10 mol, and particularly about 1.5 to 5.0 mol, relative to 1 mol of the compound (I-1) having two  $X^1$  groups.

(iv) In the case where the phosphorus-containing compound of the formula (Id) is prepared, the amount of the phosphorus compound (I-2) is, for example, about 0.1 to 5 mol, preferably about 0.2 to 3 mol, more preferably about 0.5 to 2 mol, particularly about 1 to 2 mol, relative to 1 mol of the compound (I-1) having two  $X^1$  groups.

(v) In the production of the phosphorus-containing compound of the formula (Ie) or (IIa), the amount of the phosphorus compound (I-2) is, for example, about 0.1 to 50 mol relative to 1 mol of the compound (I-1) having one  $X^1$  group, about 0.5 to 150 mol equivalent relative to 1 25 mol of the compound (I-1) having two  $X^1$  groups, and further is about 0.5 to 200 mol equivalent, relative to 1 mol of the compound (I-1) having four  $X^1$  groups.

(vi) In the case where the phosphorus-containing compound of the formula (If) is prepared, the amount of the phosphorus compound (I-2) is, for example, about 0.5 to 100 mol, relative to 1 mol of the compound (I-3).

5 The amount of the compound of the formula (III-1) can be selected within the wide range according to the object compound, and is, for example, about 0.1 to 50 mol, preferably about 0.3 to 30 mol, and more preferably about 0.5 to 10 mol, relative to 1 mol of the compound of the  
10 formula (III-2).

More concretely, (vii) in the production of the phosphorus-containing compound of the formula (IIIA), the amount of the compound of the formula (III-1) having one  $X^2$  group is, relative to 1 mol of the phosphorus compound  
15 of the formula (III-2), about 1.0 to 5.0 mol, preferably about 1.0 to 2.5 mol. Moreover, the amount of the compound of the formula (II-1) having two  $X^2$  groups is about 0.1 to 10 mol, preferably about 0.1 to 5.0 mol.

Incidentally, when a polyvalent phosphorus compound  
20 (e.g., phenylphosphoric dichloride) is used as a raw material for the compound (I-2) or (I-3), the amount of the polyvalent phosphorus compound is about 0.2 to 10 mol (e.g., 0.2 to 0.5 mol), preferably about 0.25 to 5 mol (e.g., 0.25 to 0.45 mol), and more preferably about 0.3 to 1 mol,  
25 relative to 1 mol of the compound of the formula (I-1).

The reaction described above may be conducted in the absence of a solvent, and is usually effected in the

presence of a solvent. The species of the solvent is not particularly restricted to a specific solvent so far as the reaction is not inhibited, and is exemplified a nitrogen-containing hydrocarbon which may show a basic 5 (e.g., heterocyclic compounds such as pyridine and picoline; nitrile-series solvents such as acetonitrile and benzonitrile); aliphatic hydrocarbons (e.g., hexane, heptane, octane); aromatic hydrocarbons (e.g., benzene, toluene, xylene, ethylbenzene); oxygen-containing 10 hydrocarbons (e.g., ketones such as acetone and methylethylketone; ethers such as diethylether, dibutylether, tetrahydrofuran, and 1,4-dioxane; esters such as ethyl acetate); halogenated hydrocarbons (e.g., carbon tetrachloride, chloroform, dichloromethane, 15 1,2-dichloroethane, dichlorobenzene). These solvents may be used either a sole solvent or a mixed solvent.

The preferred solvent includes pyridine, nitrile-series solvents such as acetonitrile; C<sub>6</sub>-8 aliphatic hydrocarbons such as normal hexane and normal 20 heptane; C<sub>6</sub>-12 aromatic hydrocarbons such as toluene and xylene; ethers such as diethylether, tetrahydrofuran, and 1,4-dioxane; halogenated hydrocarbons such as chloroform, dichloromethane, and 1,2-dichloroethane. Further preferably, pyridine, acetonitrile, tetrahydrofuran, 25 1,2-dichloroethane, dichloromethane and chloroform are used.

The amount of the solvent is not restricted so far

as the reaction is not adversely affected, and is, for example, about 0.1 to 500 mol, preferably about 1 to 100 mol, more preferably about 1 to 50 mol, relative to 1 mol of the compound represented by the formula (I-1), (II-5 1) or (III-1).

The objective phosphorus-containing compound represented by the formula (I) or (II) can be obtained by a dehalogenation reaction when  $X^2$  in the compound (I-2) or (II-1) is halogen atom, a dehydration reaction when  $X^2$  10 in the compound (I-2) or (II-1) is hydroxyl group, or a transesterification reaction when  $X^2$  in the compound (I-2) or (II-1) is alkoxy group. The reaction described above may be effected in the presence or absence of a catalyst.

Particularly, when the  $X^2$  is halogen atom in the 15 compound of the formula (I-2), (II-2) or (III-1), the reaction may be effected in the presence of a dehydrohalogenation reagent. As the dehydrohalogenation reagent, there are exemplified various compounds including the following compound;

20 (i) amines

primary amines [ $C_{1-8}$ alkylamines (aliphatic primary amines) such as t-butylamine, t-pentylamine, t-hexylamine, and t-octylamine;  $C_{3-8}$ cyclohexylamines (alicyclic primary amines) such as cyclohexylamine;  $C_{6-10}$ arylamines (aromatic 25 primary amines) such as aniline], secondary amines [di $C_{1-8}$ alkylamines (aliphatic secondary amines) such as di-t-butylamine, di-t-pentylamine, di-t-hexylamine, and

di-t-octylamine; diC<sub>3-8</sub>cyclohexylamines (alicyclic secondary amines) such as dicyclohexylamine; C<sub>1-4</sub>alkylanilines (aromatic secondary amines) such as N-methylaniline], tertiary amines [triC<sub>1-8</sub>alkylamines 5 (aliphatic tertiary amines) such as trimethylamine and triethylamine; triC<sub>3-8</sub>cyclohexylamines (alicyclic tertiary amines) such as tricyclohexylamine; N,N-diC<sub>1-4</sub>alkylanilines (aromatic tertiary amines) such as N,N-diethylaniline];

10 (ii) aromatic cyclic bases  
for example, 5-membered cyclic compounds (heterocyclic compounds having one to three nitrogen(s) such as pyrrole, 3-pyrroline, pyrazole, 2-pyrazoline, imidazole, 1,2,3-triazole, and 1,2,4-triazole), 6-membered cyclic compounds (heterocyclic compounds having 15 one to three nitrogen(s) such as pyridine; N-substituted pyridines such as 4-dimethylaminopyridine, 2-piperidinopyridine, 3-piperidinopyridine, 4-piperidinopyridine, 2-pyriridinopyridine, 3-pyriridinopyridine, and 4-pyriridinopyridine; 20 pyridazine; pyrimidine; pyrazine; N-substituted pyrazine such as 2-methylpyrazine; s-triazine; picoline), polycyclic heterocyclic compounds (condensed heterocyclic compounds of an aromatic hydrocarbon ring and a heterocycle 25 such as indole, quinoline, isoquinoline, cinnoline, quinoxaline, quinazoline, phthalazine, and 1,10-phenanthroline; and assembled heterocyclic compounds such

as 2,2-bipyridyl ring);

(iii) aliphatic cyclic bases

for example, 5-membered cyclic compounds (e.g.,  
5 pyrrolidine; N-substituted pyrrolidines such as N-  
5 methylpyrrolidine, 2-methylpyrrolidine, 3-  
methylpyrrolidine, 2-aminopyrrolidine, and 3-  
aminopyrrolidine; pyrazolidine), 6-membered cyclic  
compounds (piperidine; N-substituted piperidines such as  
N-methylpiperidine, o-aminopiperidine, m-aminopiperidine,  
10 and p-aminopiperidine; piperylhydrazine; morpholine;  
piperazine; N-substituted piperazines such as N-  
methylpiperazine, 2-methylpiperazine, and N,N-  
dimethylpiperazine); polycyclic heterocyclic compounds  
(crosslinked cyclic compounds such as quinuclidine,  
15 1,4-diazabicyclo[2.2.2]octane, 1,5-diazabicyclo[3.2.1]  
octane, 1,5-diazabicyclo[3.3.0]octane, 1,4-diazabicyclo  
[4.2.0]octane, 1,5-diazabicyclo[3.3.1]nonane, 1,5-diaza  
bicyclo[5.3.0]decane, 1,5-diazabicyclo[3.3.0.0<sup>2.6</sup>]  
octane, 1,8-diazabicyclo[5.4.0]undeca-7-ene, 1,5-diaza  
20 bicyclo[4.3.0]nona-5-ene, and hexamethylenetetramine);

(iv) amides (e.g., N,N-diC<sub>1-4</sub>alkyl substituted  
amides such as N,N-dimethylformamide and N,N-  
dimethylacetamide);

(v) hydroxides of alkaline metal or alkaline earth  
25 metal (e.g., sodium hydroxide, calcium hydroxide).

The preferred catalyst includes the tertiary amines  
(tri-C<sub>1-4</sub>alkylamines such as triethylamine), the aromatic

cyclic bases (preferably 6-membered heterocyclic compounds such as pyridine and picoline), the aliphatic cyclic bases (e.g., 6-membered heterocyclic compounds such as piperazine and N-methylpiperazine, quinuclidine, 5 1,4-diazabicyclo[2.2.2]octane, and hexamethylene tetramine), the amides (e.g., N,N-dimethylformamide), the metal hydroxide (e.g., sodium hydroxide). Particularly the preferred catalysts are pyridine etc.

10 The amount of the dehydrohalogenation reagent can be selected within the range of about 0.5 to 50 mol, and preferably about 1 to 30 mol, relative to 1 mol of the compound of the formula (I-2), (II-2) or (III-1).

15 More concretely, (i) when the phosphorus-containing compound of the formula (Ia) is prepared, the amount of the dehydrohalogenation reagent is about 0.5 to 30 mol, and preferably about 1.0 to 15 mol, relative to 1 mol of the compound of the formula (I-2) or (II-2).

20 (ii) When the phosphorus-containing compound of the formula (Ib) is produced, the amount of the dehydrohalogenation reagent is about 0.5 to 30 mol, and preferably about 1.0 to 15 mol, relative to 1 mol of the compound of the formula (I-2).

25 (iii) In the production of the phosphorus-containing compound of the formula (Ic), the amount of the dehydrohalogenation reagent is about 0.5 to 30 mol, and preferably about 1.0 to 15 mol, relative to 1 mol of the compound of the formula (I-2).

(iv) When the phosphorus-containing compound of the formula (Id) is prepared, the amount of the dehydrohalogenation reagent is about 0.5 to 30 mol, and preferably about 1.0 to 15 mol, relative to 1 mol of the 5 compound of the formula (I-2).

(v) In the production of the phosphorus-containing compound of the formula (Ie) or (IIa), the amount of the dehydrohalogenation reagent is about 0.5 to 5.0 mol, and preferably about 0.7 to 2.5 mol, relative to 1 mol of the 10 compound of the formula (I-2) or (II-2).

(vi) When the phosphorus-containing compound of the formula (If) is prepared, the amount of the dehydrohalogenation reagent is about 0.5 to 30 mol, and preferably about 1.0 to 15 mol, relative to 1 mol of the 15 compound of the formula (I-2).

(vii) The phosphorus-containing compound of the formula (IIa) is prepared by using the dehydrohalogenation reagent in an amount of about 2 to 10 mol, and preferably about 2.5 to 7 mol, relative to 1 mol of the compound of 20 the formula (II-1).

Incidentally, the dehydrohalogenation reagent (e.g., pyridine) may be used as a solvent.

Moreover, in the compound of the formula (I-2), (II-2) or (III-1), when  $X^2$  is hydroxyl group and/or alkoxy group, a conventional catalyst (acid catalyst, basic catalyst) may be used in the reaction (dehydration and/or transesterification). As the acid catalyst, there may be 25

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exemplified a Lewis acid such as aluminium chloride, magnesium chloride, titanium tetrachloride, antimony pentachloride, zinc chloride, and tin chloride; and a mineral acid such as sulfuric acid and hydrochloric acid.

5 Moreover, as the basic catalyst, there are exemplified amines ( $C_{1-8}$ alkylamines such as t-butylamine, t-pentylamine, t-hexylamine, and t-octylamine; di $C_{1-8}$ alkylamines such as di-t-butylamine, di-t-pentylamine, di-t-hexylamine, and di-t-octylamine; tri $C_{1-8}$ alkylamines such as trimethylamine, triethylamine, and tributylamine), and hydroxides of alkaline metal or alkaline earth metal (e.g., sodium hydroxide, calcium hydroxide).

Incidentally, the order of the addition of each component is not restricted, for example, when the 15 dehydrohalogenation is effected (the case in which  $X^2$  is halogen atom), at first the compound of the formula (I-1) (including the formula (I-3)), (II-1) or (II-2) may be dissolved in the solvent mentioned above, and the compound of the formula (I-2), (II-2) or (III-1) may be added to 20 the reaction system to react each other. Moreover, when the dehydrohalogenation reagent is used, the dehydrohalogenation reagent may be dissolved in the solvent together with the compound of the formula (I-1), (II-1) or (III-2), and may be added by dropping etc with 25 or after adding the compound of the formula (I-2), (II-2) or (III-1).

Moreover, when the dehydration or

transesterification is effected, for example, the compound of the formula (I-1), (II-1) or (III-2) and the compound of the formula (I-2), (II-2) or (II-1) may be reacted in the solvent mentioned above.

5        The reaction temperature may be selected within the range of about -80°C to 250°C (e.g., about -10°C to 250°C), and is, for example, about -80°C to 200°C, preferably about -50°C to 180°C, more preferably about -20°C to 150°C, and particularly about 0°C to 150°C (e.g., about 10°C to 120°C).

10      Incidentally, when the compound represented by the formula (Ie) is prepared, too high reaction temperature is not preferred since the object compound is liable to decompose. Therefore, the reaction temperature can be selected within the range of about -80°C to 100°C, and is preferable, for example, about -50°C to 50°C, and preferably -20°C to 30°C.

15

The reaction may be conducted under ordinary pressure, reduced pressure, or applied pressure. The reaction may be carried out in an atmosphere of an inert gas (e.g., nitrogen, argon, helium).

20      After the completion of the reaction, the phosphorus-containing compound (I), (II) and (III) formed in the above-described reaction can easily be separated and purified by such a conventional means as filtration, condensation, distillation, extraction, crystallization, recrystallization, column chromatography, or a combination means thereof.

25

Since the phosphorus-containing compound of the

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present invention is excellent in heat resistance and stability, the phosphorus-containing compound is useful as additives (flame retardants, stabilizer such as antioxidant) to improve the properties of various 5 materials [e.g., materials required heat resistance and stability such as adhesives (e.g., hot-melt adhesives, thermosensitive tackifiers, delayed tack adhesives), materials for photography and printing (e.g., image-receiving materials for forming an image by thermal 10 transfer, photosensitizer for color photography, melttable inks for ink jet), shock-absorbing materials, and pencil lead], and organic compounds or a mixture thereof (e.g., organic polymer compounds such as lubricants and heat transfer mediums). Further, the phosphorus-containing 15 compound is useful as plasticizers for resins. Moreover, since the phosphorus-containing compound of the present invention not only imparts high flame retardancy to resins but also has a low volatility, the phosphorus-containing compound is excellent in handling and useful as stabilizer 20 such as flame retardant.

The characteristics or properties of resins and a flame-retardancy level can be improved by addition of the phosphorus-containing compound of the present invention to various resins, particularly resins for molding. The 25 resin includes, for example, thermoplastic resins [e.g., olefinic resins (e.g., polypropylene-series resins, polyethylene-series resins), halogen-containing resins

(e.g., vinyl chloride), acrylic resins [e.g., poly(meth)acrylates such as polymethyl methacrylate], styrenic resins [e.g., polystyrene, rubber-grafted styrenic resins or rubber-reinforced styrenic resins (e.g., 5 HIPS, acrylonitrile-rubber component (e.g., butadiene)-styrene copolymers (e.g., ABS resins), acrylonitrile-styrene copolymers (SAN resins)], polycarbonate-series resins, polyester-series resins (e.g., polyalkylene arylates such as polyethylene terephthalate and 10 polybutylene terephthalate), polyethylene ether-series resin, polyphenylene sulfide-series resins, polyamide-series resins (e.g., aliphatic polyamides such as nylon 6 and nylon 12, aromatic nylons), polyurethane resins, polyether-series resins (e.g., polyacetal resins, 15 polyarylate resins, denatured polyphenylene resins (e.g., PPO)], thermosetting resins (e.g., alkyd resins, allyl resins, epoxy resins, hard urethane resins, soft urethane resins, phenolic resins, melamine resins, guanamine resins, xylene resins, acrylic resins, unsaturated polyester 20 resins, silicone resins, urea resins, butadiene-series resins, polyimide resins).

Moreover, the resins may be copolymer resins [e.g., methyl methacrylate-butadiene-styrene copolymers (MBS resins), styrene-maleic anhydride copolymers, styrene-25 methacrylic acid copolymers] and alloys (e.g., an alloy of ABS resin or HIPS resin and polycarbonate-series resin, an alloy of ABS resin and polyester-series resin, an alloy

of ABS resin and polyamide-series resin).

Among the thermoplastic resins or the thermosetting resins, the styrenic resins may be a homopolymer or a copolymer of styrene and styrene derivatives such as  $\alpha$ -substituted or nucleus (aromatic ring)-substituted styrene. Moreover, the styrenic resins also include a copolymer, in which a predominant component is the above mentioned monomer, and other component is a vinyl compound (e.g., acrylonitrile, acrylic acid, methacrylic acid) and/or a conjugated diene compound (e.g., butadiene, isoprene). As such styrenic resins, there are exemplified polystyrene, high impact polystyrene (HIPS), acrylonitrile-butadiene-styrene copolymer (ABS resin), acrylonitrile-styrene copolymer (AS resin), styrene-methacrylate copolymer (MS resin), styrene-butadiene copolymer (SBS resin).

Moreover, the styrenic resin and other resins (particularly the polycarbonate-series resin) may be used in combination. The ratio of the styrenic resin to the other resin may be the former/the latter (weight ratio) = about 50/50 to 15/85, and preferably about 40/60 to 20/80.

When the phosphorus-containing compound is used as an additive for the resins, the amount of the phosphorus-containing compound is not restricted so far as the properties of the resins are not adversely affected, and is, relative to 100 parts by weight of resins, about 1 to 40 parts by weight, and preferably about 3 to 25 parts

by weight.

Incidentally, so far as the properties of the resins are not deteriorated, to the resins, other additives [e.g., lubricants such as stearic acid and ethylenebisstearyl amide, flame retardants (e.g., inorganic phosphorus-series flame retardants such as red phosphorus; triazine-series flame retardants such as melamine cyanurate, melamine, and cyanuric acid; metal hydrates; borates; metal oxides), auxiliary flame retardants (e.g., 5 fluorine resins, silicone), stabilizers (e.g., antioxidants, ultraviolet-rays absorbent), dyes, pigments, fillers (e.g., glass fiber, carbon fiber, wollastonite, calcium carbonate, talc, mica, wood flour, slate powder, fibrous asbestos) may be added in addition to the 10 phosphorus-containing compound of the present invention. 15

A resin composition comprising the resins and various additives (e.g., phosphorus-containing compound) can be produced by a conventional kneading technique (e.g., the use of kneading machines such as extruder, heat(hot) roll, 20 kneader, and Banbury mixer).

Such resin compositions are excellent in flame retardancy and heat resistance, and thus can be used over wide applications [e.g., parts for a variety of fields (OA equipment fields, fields for electrical household 25 appliances and electrical equipment, electrical and electronics fields, telecommunication equipment fields, sanitation fields, car fields, fields for accommodation

unit such as furniture and building materials, general merchandise fields), housing, chassis].

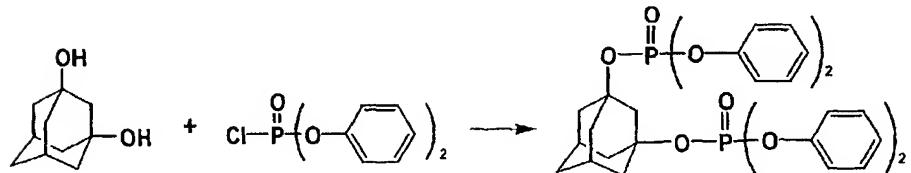
#### INDUSTRIAL APPLICABILITY

5 Since the phosphorus-containing compound of the present invention has a specific ring structure, the phosphorus-containing compound is excellent in heat resistance, and a combination of the phosphorus-containing compound with various materials (particularly resins for 10 molding) can markedly improve the properties (e.g., stability) of the composition.

#### EXAMPLES

15 The following examples are intended to describe this invention in further detail and should by no means be interpreted as defining the scope of the invention.

##### Example A1



20 Adamantylbis(diphenylphosphate) was prepared according to the reaction scheme.

Into a three-neck flask (500ml) equipped with a dropping funnel, a Dimroth condenser and a calcium chloride

(CaCl<sub>2</sub>) tube, were fed 40.1g (238mmol) of adamantanediol and 235.1g (2.97mol) of pyridine, and 159.7g (595mmol) of diphenylphosphorochloride was added dropwise to the mixture for 30 minutes at 60°C with stirring. After 5 dropping was completed, the reaction was effected at 90°C for 2.5 hours.

The reaction mixture was cooled to room temperature, and 400ml of ethyl acetate and 400ml of water were added to the reaction mixture for extraction of an object compound.

10 Further, an organic layer was washed with 400ml of 2N (2mol/L) hydrochloric acid three times, 400ml of saturated sodium carbonate aqueous solution three times, and 400ml of water one time in this order. The organic layer was dried with sodium sulfate and evaporated.

15 The obtained oil was recrystallized with a mixed solvent of ethyl acetate (90ml) and hexane (200ml) to obtain adamantylbis(diphenylphosphate). The result of <sup>1</sup>H NMR is shown in Figure 1, and the result of IR spectrum is shown in Figure 2.

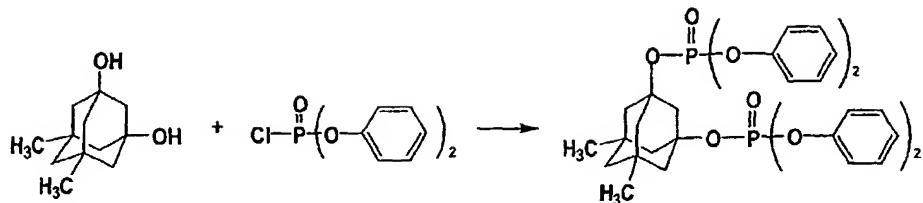
20 yield (weight) : 106.5g

yield (ratio) : 71%

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>, ppm) : 7.33 to 7.15 (m, 20H), 2.48 (s, 2H), 2.39 (s, 2H), 2.13 to 2.04 (q, 8H), 1.52 (s, 2H)

25 IR spectrum (cm<sup>-1</sup>) : 2926, 1590, 1491 (benzene ring), 1300, 1281 (P=O), 1194 (P-O-C(aromatic)), 984(P-O-C), 957(P-O-C), 932(P-O-C)

Example A2



Dimethyladamantylbis(diphenylphosphate) was  
5 prepared according to the reaction scheme.

Into a three-neck flask (500ml) equipped with a  
dropping funnel, a Dimroth condenser and a calcium chloride  
( $\text{CaCl}_2$ ) tube, were fed 42.2g (215mmol) of dimethyl  
adamantanediol and 213g (2.69mol) of pyridine, and 148g  
10 (55.1mmol) of diphenylphosphorochloridate was added  
dropwise to the mixture for 30 minutes at 60°C with stirring.  
After dropping was completed, the reaction was effected  
at 90°C for 7 hours.

The reaction mixture was cooled to room temperature,  
15 and 400ml of ethyl acetate and 400ml of water were added  
to the reaction mixture for extraction of an object compound.  
Further, an organic layer was washed with 400ml of 2N  
(2mol/L) hydrochloric acid three times, 400ml of saturated  
sodium carbonate aqueous solution three times, and 400ml  
20 of water one time in this order. The organic layer was dried  
with sodium sulfate and evaporated.

The resultant residue was dissolved in a mixed  
solvent of ethyl acetate (90ml) and hexane (200ml) and

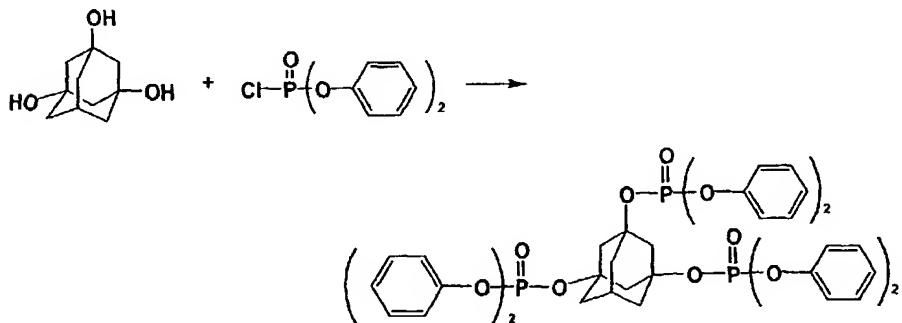
recrystallized from the solvent to obtain  
dimethyladamantylbis(diphenylphosphate).

yield (weight) : 107g

yield (ratio) : 75%

5        $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ , ppm) : 7.36 to 7.15 (m, 20H),  
2.38 (s, 2H), 1.79 (s, 8H), 1.12 (s, 2H), 0.96 (s, 6H)  
IR spectrum ( $\text{cm}^{-1}$ ) : 1592, 1489 (benzene ring), 1293  
(P=O), 1194 (P-O-C(aromatic)), 994 (P-O-C), 951 (P-O-C),  
932(P-O-C)

10       Example A3



Adamantyltris(diphenylphosphate) was prepared  
according to the reaction scheme.

15       Into a three-neck flask (500ml) equipped with a  
dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube were  
fed 20g (109mmol) of adamantanetriol and 150g (1.9mol) of  
pyridine, and 103g (382mmol) of diphenylphosphoric  
chloride was added dropwise to the mixture for 25 minutes  
20       at 70°C under stirring. After dropping was completed, the

reaction was effected under 90°C for 7 hours.

The reaction mixture was cooled to room temperature, and 300ml of dichloromethane was added to the reaction mixture for extracting an object compound. Further, the 5 extract was washed with 170ml of 2N (2mol/L) hydrochloric acid three times, 300ml of water one time, 300ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 300ml of water one time in this order. The organic layer was dried with sodium sulfate, and then solvents were evaporated to 10 obtain the objective adamantlylris(diphenylphosphate) as light-yellow oil.

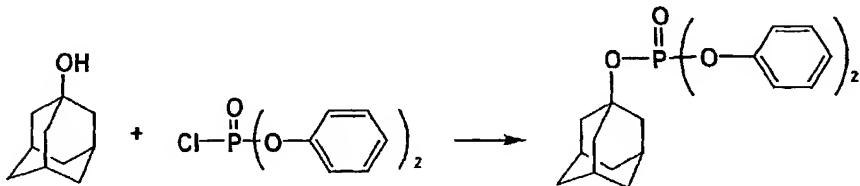
yield (weight) : 81.3g

yield (ratio) : 85%

IR spectrum (NEAT,  $\text{cm}^{-1}$ ) : 1593, 1491, 1289, 1217, 15 1190, 1163, 1103, 1019

$^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ , ppm) : 7.31 to 7.14 (m, 30H), 2.55 to 2.48 (q, 7H), 2.03 (s, 6H)

Example B1



20

Adamantyldiphenylphosphate was prepared according to the reaction scheme.

Into a flask provided with a thermometer, a stirring

equipment, a dropping funnel, a  $\text{CaCl}_2$  tube, and a condenser, were fed 45g (0.29mol) of 1-adamantanol and 117g (1.5mol) of pyridine, and were stirred at 60°C. 95g (0.35mmol) of diphenylphosphoric chloride was added dropwise with 5 vigorously stirring. After dropping was completed, the reaction was effected at 90°C for 3 hours. After the reaction mixture was cooled to room temperature, 700ml of ethyl acetate was added to the reaction mixture, and the mixture was washed with 700ml of water two times, 700ml 10 of 1N (1mol/L) hydrochloric acid three times, 700ml of 15% by weight  $\text{Na}_2\text{CO}_3$  aqueous solution three times, and 700ml of water two times in this order. After an organic layer was dried with sodium sulfate and solvents were evaporated, the resultant residue was crystallized from a mixed solvent 15 of ethyl acetate and hexane (1:2) to obtain the objective adamantlydiphenyl phosphate. The result of  $^1\text{H}$  NMR is shown in Figure 3, and the result of IR spectrum is shown in Figure 4.

yield (weight) : 109g

20 yield (ratio) : 97%

purity : 98.6% (GC area ratio)

melting point : 47°C

thermal decomposition temperature : 220°C

mass spectroscopy : m/Z 384

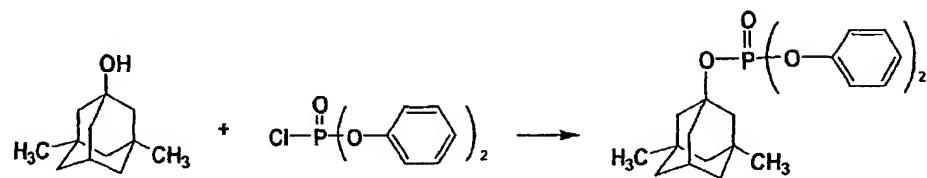
25  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , ppm) : 7.35 to 7.16 (m, 10H, phenyl), 2.20 (s, 3H, bridgehead), 2.14 (d, 6H, 2-position, 8-position, 10-position), 1.63 (t, 6H, 4-position, 6-

position, 9-position)

IR spectrum (cm<sup>-1</sup>) : 2910 to 2855, 1590, 1489, 1285,  
1192, 1017, 945, 775, 688

Example B2

5



Dimethyladamantyl diphenylphosphate was prepared according to the reaction scheme.

10 Into a flask provided with a thermometer, a stirring equipment, a dropping funnel, a  $\text{CaCl}_2$  tube, and a condenser were fed 28g (0.16mol) of dimethyl-1-adamantanol and 61g (0.78mol) of pyridine, and the mixture was stirred at 60°C. To the mixture, 50g (0.19mol) of diphenylphosphoric chloride was added dropwise under vigorously stirring.

15 After dropping was completed, the reaction was effected at 90°C for 3 hours. After the reaction mixture was cooled to room temperature, 300ml of ethyl acetate was added to the reaction mixture, and the mixture was washed with 300ml of water two times, 300ml of 1N (1mol/L) hydrochloric acid three times, 300ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution three times, and 300ml of water two times in this order, and was dried with sodium sulfate. After solvents were evaporated, the residue was crystallized from a mixed

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solvent of ethyl acetate and hexane (1:2) to obtain the objective dimethyladamantyldiphenylphosphate.

yield (weight) : 64g

yield (ratio) : 99%

5 purity : 96.7% (GC area ratio)

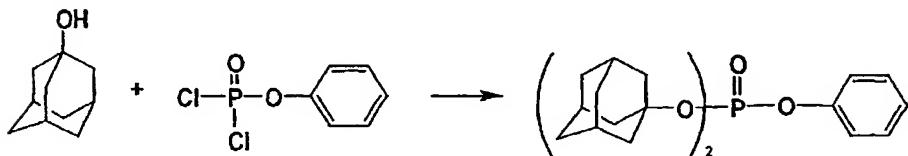
thermal decomposition temperature : 233°C

10  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ , ppm) : 7.33 (t, 2H, m-phenyl), 7.21 to 7.23 (m, 2H, o-phenyl), 7.16 (t, 1H, o-phenyl), 2.21 to 2.26 (m, 1H, bridgehead), 1.95 (d, 2H), 1.75 to 1.84 (q, 4H), 1.24 to 1.38 (q, 4H), 1.10 to 1.19 (m, 2H), 0.85 (s, 6H)

15 IR spectrum (NEAT,  $\text{cm}^{-1}$ ) : 2915, 1456, 1281, 1194, 1021, 953, 758

Example B3

15



Bis(adamantyl)phenylphosphate was prepared according to the reaction scheme.

20 Into a three-neck flask (50ml) equipped with a dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube, were fed 50g (0.33mol) of adamantanol and 126g (1.6mol) of pyridine, and the reaction mixture were stirred at 60°C. Into the reaction mixture was added dropwise 33g (0.16mol)

of phenylphosphoric dichloride. After dropping was completed, the reaction was effected at 90°C for 6 hours. After complete reaction, the reaction mixture was cooled to room temperature, and 500ml of ethyl acetate was added 5 to the reaction mixture, and the mixture was washed with 750ml of water, 500ml of 2N (2mol/L) hydrochloric acid four times, 500ml of water one time, 500ml of 15 % by weight Na<sub>2</sub>CO<sub>3</sub> aqueous solution two times, and 500ml of water one time in this order, and the organic layer was dried with 10 sodium sulfate. After the solvent was evaporated, the resultant residue was crystallized from a mixed solvent of ethyl acetate and hexane (1:1.1) to obtain the objective bis(adamantyl)phenylphosphate.

yield (weight) : 59g

15 yield (ratio) : 85%

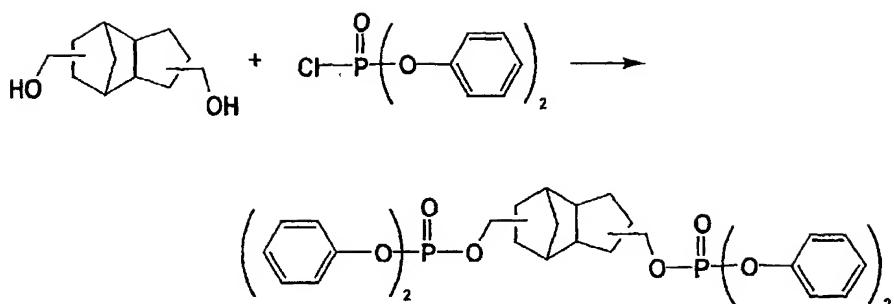
melting point : 120°C

thermal decomposition temperature : 253°C

1 H NMR (500 MHz, CDCl<sub>3</sub>, ppm) : 7.32 (t, 2H), 7.22 (d, 2H), 7.11 (t, 1H), 2.17 (s, 6H), 2.11 (d, 12H), 1.63 (s, 20 12H)

IR spectrum (cm<sup>-1</sup>) : 2911, 1489, 1264, 1215, 1069, 1009, 934

Example C1



3,4- or 4,9-bis[(diphenylphosphoroxy)methyl] tricyclo[5.2.1.0<sup>2,6</sup>]decane was prepared according to the 5 above mentioned reaction scheme.

10 Into a three-neck flask (500ml) equipped with a dropping funnel, a Dimroth condenser and a calcium chloride tube, were fed 53.8g (0.27mol) of tricyclo[5.2.1.0<sup>2,6</sup>] decane-3,8- or 4,9-dimethanol (manufactured by Celanese Co. Ltd., USA) and 273g (3.4mol) of pyridine, and were stirred at 60°C. After 183g (0.68mol) of diphenylphosphoro chloride was added dropwise into the reaction mixture for 30 minutes, the reaction was effected at 90°C for 6 hours to complete the reaction.

15 The reaction mixture was cooled to room temperature, and an object was extracted with 500ml of ethyl acetate. An organic layer was washed with water, 2N (2mol/L) hydrochloric acid, water, 15 % by weight Na<sub>2</sub>CO<sub>3</sub> aqueous solution, and water in this order, was dried with sodium sulfate, and the solvent was evaporated to obtain the object 20 compound as light-yellow oil.

yield (weight) : 173.8g

yield (ratio) : 96%

purity : 98% (High Performance Liquid Chromatography

(HPLC) area ratio)

5 melting point : 117°C

thermal decomposition temperature : 277°C

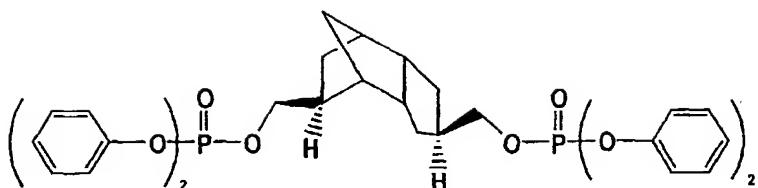
IR spectrum (NEAT,  $\text{cm}^{-1}$ ) : 3009, 2955, 1592, 1491,  
1287, 1192, 1024, 957, 689

10  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , ppm) : 7.36 to 7.16 (m, 20H),  
4.10 to 3.96 (m, 4H), 2.49 to 2.21 (m, 3H), 2.15 to 1.95  
(m, 3H), 1.74 to 1.18 (m, 7H), 0.95 to 0.84 (m, 1H)

Example C2

15 (4R,8S)-bis(diphenylphosphoroxyethyl)-  
(1R,2S,6R,7R)-tricyclo[5.2.1.0<sup>2,6</sup>]decane was isolated by  
the following method.

The oil obtained by the Example C1 mentioned above  
was recrystallized from a mixed solvent of ethyl acetate  
and hexane to obtain (4R,8S)-bis(diphenylphosphoroxy  
methyl)-(1R,2S,6R,7R)-tricyclo[5.2.1.0<sup>2,6</sup>]decane as  
white crystal. The obtained white crystal was analyzed by  
HPLC, and one peak was found at 18.2 minutes. The structure  
was determined by  $^1\text{H}$  NMR spectrum,  $^{13}\text{C}$  NMR spectrum, DEPT  
spectrum, COSY spectrum, and HETCOR spectrum. The yield  
of the recrystal was 25%.



melting point : 91°C

thermal decomposition temperature : 264°C

5 IR spectrum (cm<sup>-1</sup>) : 2957, 1592, 1489, 1293, 1190, 1040, 1011, 954, 939, 777, 760, 691

10 <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>, ppm) : 7.36 to 7.16 (m, 20H), 4.10 to 4.06 (m, 2H), 3.99 to 3.94 (m, 2H), 2.49 to 2.38 (m, 2H), 2.32 to 2.21 (m, 1H), 2.10 (s, 1H), 2.05 (d, 1H), 2.03 to 1.95 (m, 1H), 1.64 to 1.61 (m, 2H), 1.56 to 1.49 (m, 1H), 1.37 (q, 2H), 1.27 to 1.21 (m, 2H), 0.92 to 0.85 (m, 1H)

(analysis condition of HPLC)

column (manufactured by YMC, J'sphere ODS-M80

15 JM08S04-2546WT; 250mm×4.6mm), eluate (acetonitrile:water = 60:40), flow rate (0.8mL/minute), wavelength of measurement (260nm), temperature of column oven (40°C)

#### Example D1

20 Into a three-neck flask (1000ml) equipped with a dropping funnel and a calcium chloride tube, were fed 25.4g (0.18mol) of p-xylyleneglycol, 190.8g of acetonitrile, and 50.9g (0.64mol) of pyridine, and the reaction mixture was stirred at 3.5°C. Into the reaction system, 98.8g

(0.37mol) of diphenylphosphoric chloride was added dropwise for 45 minutes, and the reaction was effected at 2.0 to 9.5°C for 1.5 hours to complete the reaction. Complete consumption of p-xylyleneglycol of raw material 5 was determined by HPLC.

The reaction mixture was put into 1300g of ice water, and the object compound was deposited and was filtered. The object compound was washed with 200ml of cool methanol, and was filtered. The objective p-xylyleneglycolbis 10 (diphenylphosphate) was recrystallized from 200ml acetonitrile to be purified.

yield (weight) : 99.6g

yield (ratio) : 90%

purity : 95% (HPLC area ratio)

15 melting point : 101°C (thermal decomposition temperature : 241°C)

(analysis condition of HPLC)

column (manufactured by YMC, J'sphere ODS-M80 JM08S04-2546WT, 250mm×4.6mm), eluate 20 (acetonitrile:water=60:40 to 80:20), flow rate (0.8mL/min), wavelength of measurement (254nm), temperature of column oven (40°C)

IR spectrum ( $\text{cm}^{-1}$ ) : 1590, 1489, 1293, 1192, 1015, 957, 816, 777, 691, 532, 504

25  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , ppm) : 7.33 to 7.16 (m, 24H), 5.25 to 5.24 (d, 4H)

Example D2

Into a three-neck flask (1000ml) equipped with a dropping funnel and a calcium chloride tube, were fed 35.1g (0.25mol) of *o*-xylyleneglycol, 160.2g of acetonitrile, 70.3g (0.89mol) of pyridine, and 136.3g (0.51mol) of 5 diphenylphosphoric chloride, and the reaction was effected by a method similar to the method of Example 1, and a reaction product was purified by column chromatography to obtain the objective *o*-xylyleneglycolbis(diphenylphosphate) as colorless 10 liquid.

yield (weight) : 140.8g  
yield (ratio) : 92%  
purity : 98% (HPLC area ratio)  
thermal decomposition temperature : 225°C  
15 IR spectrum (cm<sup>-1</sup>) : 1590, 1489, 1291, 1217, 1190, 1161, 1011, 953, 754, 689  
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>, ppm) : 7.40 to 7.09 (m, 24H), 5.25 to 5.24 (d, 4H)

Example D3  
20 Into a three-neck flask (1000ml) equipped with a dropping funnel and a calcium chloride tube, were fed 50.0g (0.36mol) of *m*-xylyleneglycol, 372.7g of acetonitrile, 100.2g (1.3mol) of pyridine, and 194.7g (0.73mol) of diphenylphosphoric chloride, and the reaction was effected 25 by a method similar to the method of Example 1, and a reaction product was purified by column chromatography to obtain the objective *m*-

xyloleneglycolbis(diphenylphosphate).

yield (weight) : 196.2g

yield (ratio) : 90%

purity : 97% (HPLC area ratio)

5 IR spectrum (cm<sup>-1</sup>) : 1590, 1487, 1289, 1215, 1188, 1155, 1024, 1010, 947, 754, 689

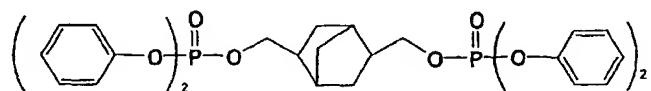
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>, ppm) : 7.34 to 7.15 (m, 24H), 5.21 to 5.19 (d, 4H)

Comparative Example D1

10 Into a three-neck flask (100ml) equipped with a dropping funnel, a Dimroth condenser and calcium chloride tube, were fed 2.5g (18mmol) of p-xyloleneglycol, 19g of acetonitrile, and 5.1g (64mmol) of pyridine, and the reaction mixture was stirred at room temperature. After 15 9.9g (37mmol) of diphenylphosphate was added dropwise into the reaction system for 30 minutes, the reaction was effected at 68°C for 1.5 hours to complete the reaction.

The reaction mixture was analyzed by HPLC, and the peak corresponding to the objective compound was not found.

20 Example E1



2,5-bis(diphenylphosphoroxymethyl)norbornane was prepared according to the above reaction scheme.

Into a three-neck flask (300ml) equipped with a dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube, were fed 19.3g (147mmol) of norbornanediethanol and 147g (1.86mol) of pyridine, and 83.1g (309mmol) of diphenylphosphoric chloride was added dropwise for 30 minutes at 60°C with stirring. After dropping was completed, the reaction was effected at 90°C for 4 hours.

The reaction mixture was cooled to room temperature, and an object compound was extracted with 300ml of dichloromethane, and an organic layer was washed with 170ml of 2N (2mol/L) hydrochloric acid three times, 300ml of water one time, 300ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 300ml of water one time in this order. After the organic layer was dried with sodium sulfate, the solvent was evaporated to obtain the objective 2,5-bis(diphenyl phosphoroxymethyl)norbornane.

20           yield (weight) : 70.6g

yield (ratio) : 92%

IR spectrum ( $\text{cm}^{-1}$ ) : 2953, 1590, 1489, 1456, 1296, 1217, 1192, 1163, 1021, 953, 776, 766, 691

25            $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ , ppm) : 7.33 to 7.21 (m, 20H), 4.24 to 3.95 (m, 4H), 2.23 to 0.65 (m, 10H)

Example E2

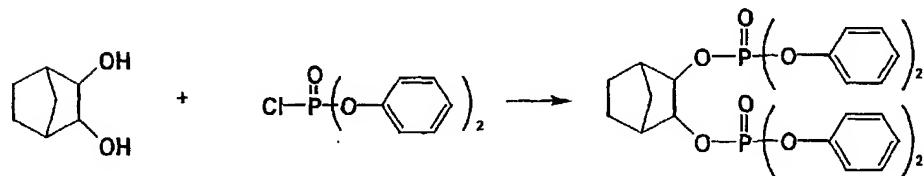


2,3-dihydroxynorbornane of a raw material for an objective compound was prepared according to the above 5 reaction scheme.

Into a four-neck flask (200ml) were fed 20.3g (185mmol) of 2,3-epoxynorbornane, 50ml of water, 25ml of acetone, and 50 $\mu$ l of sulfuric acid, and the reaction mixture was refluxed at 40°C for 6 hours. After complete reaction, 10 an object compound was extracted with each 40ml of diethylether five times, and the resultant extract was washed with saturated salt solution (braine), and was dried with sodium sulfate to obtain 2,3-dihydroxynorbornane.

yield (weight) : 20.5g

15 yield (ratio) : 87%



After that, 2,3-bis(diphenylphosphoryloxy)norbornane was prepared according to the reaction scheme.

20 Into a three-neck flask (300ml) equipped with a

dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube, were fed 10.0g (78.2mmol) of 2,3-dihydroxynorbornane and 61.7g (780mmol) of pyridine, and 52.4g (195mmol) of diphenylphosphoric chloride was added dropwise for 50 minutes at 60°C with stirring. After dropping was completed, the reaction was effected at 90°C for 6 hours.

The reaction mixture was cooled to room temperature, and an object compound was extracted with 300ml of dichloromethane, and an organic layer was washed with 170ml of 2N (2mol/L) hydrochloric acid three times, 300ml of water one time, 300ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 300ml of water one time in this order. The organic layer was dried with sodium sulfate, and the solvent was evaporated to obtain light-yellow oil. The oil was subjected to column chromatography (an eluate was ethyl acetate/hexane=5/3) to isolate the objective 2,3-bis(diphenylphosphoroxy)norbornane.

yield (weight) : 36.5g

yield (ratio) : 79%

IR spectrum (NEAT,  $\text{cm}^{-1}$ ) : 1592, 1489, 1283, 1217, 1190, 1163, 1084, 1063, 1026, 1011

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , ppm) : 7.32 to 7.13 (m, 20H), 4.77 to 4.73 (m, 2H), 2.57 (d, 1H), 2.39 (s, 1H), 2.16 (d, 1H), 2.03 to 1.97 (q, 1H), 1.66 to 1.55 (m, 2H), 1.19 to 1.08 (m, 2H)

Example E3

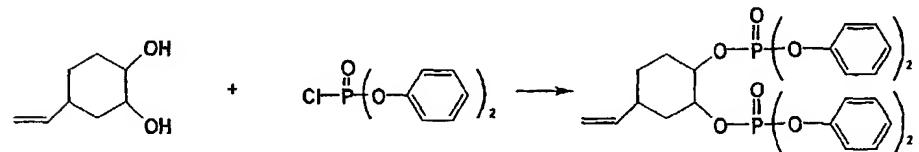


1,2-dihydroxy-4-vinylcyclohexane of a raw material for an objective compound was prepared according to the reaction scheme.

5      Into a two-neck flask (100ml) were fed 15.9g (128mmol) of 4-vinylcyclohexene-1,2-epoxide, 40ml of water, 20ml of acetone, and 40 $\mu$ l of sulfuric acid, and the reaction mixture was refluxed at 75°C for 4 hours. After complete reaction, an object compound was extracted with 10      each 60ml of diethylether four times, and was washed with saturated salt solution, and then was dried with sodium sulfate. The solvent was evaporated to obtain 1,2-dihydroxy-4-vinylcyclohexane.

yield (weight) : 16.4g

15      yield (ratio) : 90%



After that, 1,2-bis(diphenylphosphoroxy)-4-vinylcyclohexane was prepared according to the above 20      reaction scheme. Into a three-neck flask (300ml) equipped with a dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube,

were fed 9.9g (69.6mmol) of 1,2-dihydroxy-4-vinylcyclohexane and 55.6g (703mmol) of pyridine, and 46.9g (175mmol) of diphenylphosphoric chloride was added dropwise for 15 minutes at 60°C with stirring. After 5 dropping was completed, the reaction was effected at 90°C for 6 hours.

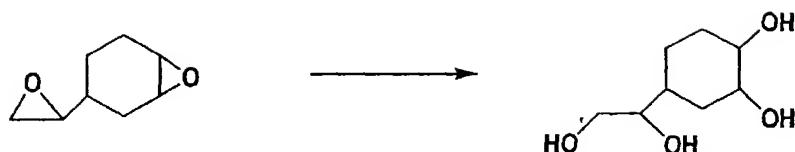
The reaction mixture was cooled to room temperature, and an object compound was extracted with 300ml of dichloromethane, and an organic layer was washed with 150ml 10 of 2N (2mol/L) hydrochloric acid three times, 300ml of water one time, 300ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 300ml of water one time in this order. The organic layer was dried with sodium sulfate, and then the solvent was evaporated to obtain light-yellow oil. The oil 15 was subjected to column chromatography (eluates were dichloromethane and ethyl acetate) to isolate the objective 1,2-bis(diphenylphosphoroxy)-4-vinylcyclohexane.

yield (weight) : 35.7g  
20 yield (ratio) : 84%

IR spectrum (NEAT,  $\text{cm}^{-1}$ ) : 1592, 1489, 1287, 1227, 1190, 1163, 1046, 1024, 1011

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , ppm) : 7.34 to 7.15 (m, 20H), 5.70 to 5.61 (m, 1H), 4.97 to 4.92 (m, 2H), 4.87 to 4.85 25 (m, 1H), 4.84 to 4.75 (m, 1H), 2.34 to 2.30 (m, 1H), 1.91 to 1.85 (m, 3H), 1.73 to 1.67 (t, 1H), 1.56 to 1.51 (m, 1H), 1.47 to 1.40 (m, 1H)

Example E4



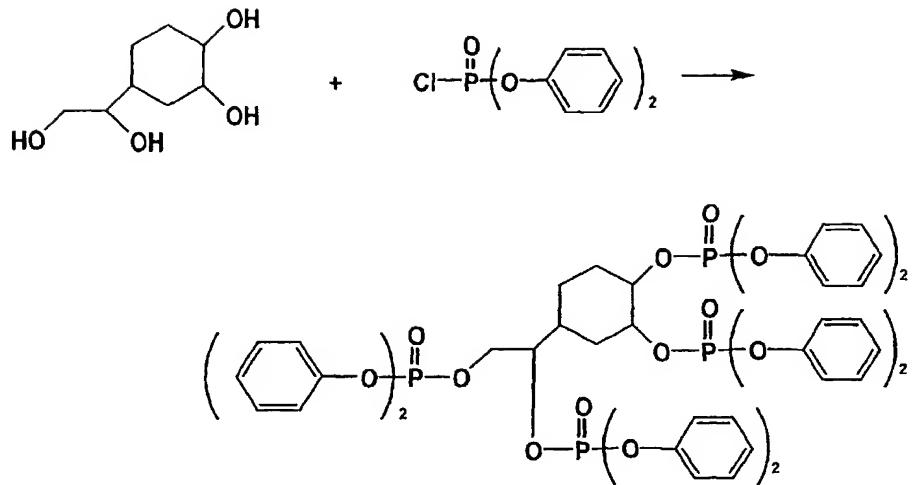
1,2-dihydroxy-4-(1',2'-dihydroxyethyl)cyclo  
hexane of raw material for an object compound was prepared  
5 according to the reaction scheme.

Into a two-neck flask (100ml) were fed 20.0g  
(143mmol) of 4-vinylcyclohexene dioxide, 50ml of water,  
25ml of acetone, and 50 $\mu$ l of sulfuric acid, and the reaction  
was effected at room temperature for 4 hours.

10 After complete reaction, the reaction mixture was  
neutralized with 10 % by weight sodium carbonate aqueous  
solution, and the solvent was evaporated to obtain  
1,2-dihydroxy-4-(1',2'-dihydroxyethyl)cyclohexane.

yield (weight) : 23.4g

15 yield (ratio) : 93%



After that, 1,2-bis(diphenylphosphoroxy)-4-[1',2'-bis(diphenylphosphoroxy)ethyl]cyclohexane  
5 was prepared according to the reaction scheme.

Into a three-neck flask (300ml) equipped with a dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube, were fed 10.0g (56.6mmol) of 1,2-dihydroxy-4-(1',2'-dihydroxyethyl)cyclohexane and 68.3g (863mol) of pyridine, 10 and 76.3g (284mmol) of diphenylphosphoric chloride was added dropwise for 30 minutes at 60°C with stirring. After dropping was completed, the reaction was effected at 90°C for 6 hours.

The reaction mixture was cooled to room temperature, 15 and an object compound was extracted with 300ml of dichloromethane, and an organic layer was washed with 170ml of 2N (2mol/L) hydrochloric acid three times, 300ml of water

one time, 300ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution  
two times, and 300ml of water one time in this order. The  
organic layer was dried with sodium sulfate, and then the  
solvent was evaporated to obtain light-yellow oil. The oil  
5 was subjected to column chromatography to isolate the  
object compound.

yield (weight) : 57.53g

yield (ratio) : 92%

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , ppm) : 7.37 to 7.15 (m, 40H),  
10 4.92 to 3.54 (m, 5H), 2.32 to 1.41 (m, 7H)

Example E5



1-diphenylphosphoroxymethyl-3-cyclohexene was  
prepared according to the reaction scheme.

Into a three-neck flask (500ml) equipped with a  
15 dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube, were  
fed 12.0g (107mmol) of 3-cyclohexen-1-methanol and 46.5g  
(588mmol) of pyridine, and 31.6g (118mmol) of  
diphenylphosphoric chloride was added dropwise for 30  
minutes at room temperature with stirring. After dropping  
20 was completed, the reaction was effected at 60°C for 5 hours.

The reaction mixture was cooled to room temperature,  
and an object compound was extracted with 300ml of  
dichloromethane, and an organic layer was washed with 150ml  
of water one time, 150ml of 2N (2mol/L) hydrochloric acid

two times, 150ml of water one time, 150ml of 10 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 50ml of water one time in this order. The organic layer was dried with sodium sulfate, and then the solvent was evaporated to obtain the 5 object compound as colorless liquid.

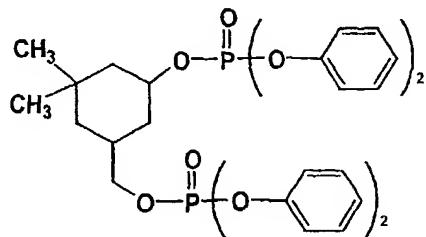
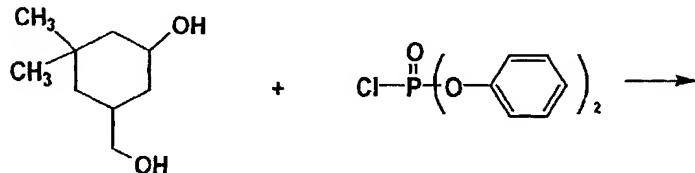
yield (weight) : 40.0g

yield (ratio) : 85%

IR spectrum (NEAT,  $\text{cm}^{-1}$ ) : 1585, 1480, 1287, 1189, 1163, 1051, 1022, 1010

10  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ , ppm) : 7.35 to 7.16 (m, 10H), 6.10 to 6.01 (m, 2H), 4.16 to 4.10 (t, 2H), 2.11 to 1.96 (m, 4H), 1.77 to 1.71 (m, 2H), 1.35 to 1.29 (m, 1H)

Example E6



15 3,3-dimethyl-5-(diphenylphosphorylmethyl)cyclohexylphosphate was prepared according to the reaction scheme.

Into a three-neck flask (200ml) equipped with a dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube, were

fed 7.0g (44mmol) of 3-hydroxymethyl-5,5-dimethylcyclohexanol and 36.2g (457mol) of pyridine, and 29.8g (111mmol) of diphenylphosphoric chloride was added dropwise for 30 minutes at 60°C with stirring. After dropping was completed, the reaction was effected at 90°C for 4 hours.

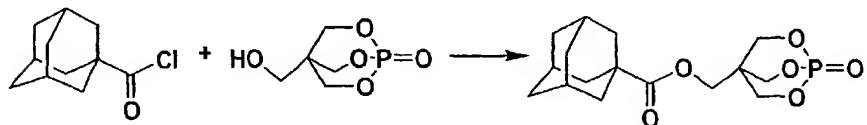
The reaction solution was cooled to room temperature, and an object compound was extracted with 300ml of dichloromethane, and an organic layer was washed with 170ml of 2N (2mol/L) hydrochloric acid three times, 300ml of water one time, 300ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 300ml of water one time in this order. The organic layer was dried with sodium sulfate, and then the solvent was evaporated to obtain the objective 3,3-dimethyl-5-(diphenylphosphoroxyethyl)cyclohexylphosphate.

yield (weight) : 24.6g

yield (ratio) : 96%

IR spectrum (NEAT,  $\text{cm}^{-1}$ ) : 3011, 2957, 1592, 1491, 1458, 1283, 1227, 1190, 1163, 1024, 1011, 1001  
 $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , ppm) : 7.36 to 7.14 (m, 20H), 5.03 to 4.99 (m, 1H), 4.03 to 4.00 (t, 2H), 2.10 (br, 1H), 1.99 to 1.95 (d, 1H), 1.80 to 1.76 (q, 1H), 1.67 (s, 1H), 1.44 to 1.40 (q, 1H), 1.28 to 1.24 (m, 1H), 1.22 to 1.14 (m, 1H), 0.92 (s, 3H), 0.85 (s, 3H)

Example F1



(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl adamantanecarbonate was prepared according to the reaction scheme.

5        Into a three-neck flask (500ml) equipped with a dropping funnel, a Dimroth condenser and a  $\text{CaCl}_2$  tube, were fed 59g (0.33mol) of 2,6,7-trioxa-1-phosphabicyclo[2.2.2]octane-4-hydroxymethyl-1-oxide and 126g (1.6mol) of

10      pyridine, and the reaction mixture was stirred at 60°C. 10      Into the reaction mixture was added dropwise 80 g (0.40mol) adamantanecarboxylic chloride dissolved in 100ml of acetonitrile, and the reaction was effected at 85°C for 5 hours.

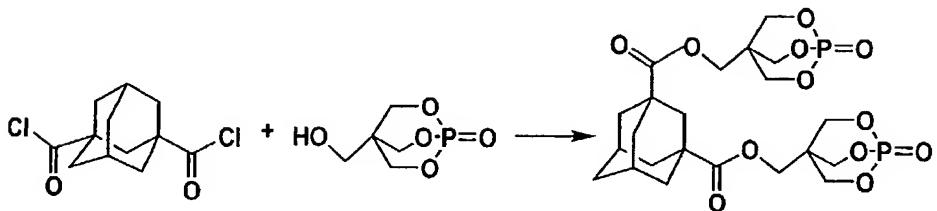
15      The reaction mixture was cooled to room temperature, and 500ml of ethyl acetate and 500ml of water was added to the reaction mixture, and the mixture was put into a separatory funnel to isolate an organic layer. The organic layer was washed with 500ml of water one time, 500ml of 15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 500ml 20      of water one time in this order. The organic layer was dried with sodium sulfate, and then the solvent was evaporated to obtain white solid. The resultant solid was washed with methanol and was dried under vacuum. The result of  $^1\text{H}$  NMR is shown in Figure 5, and the result of IR spectrum is shown 25      in Figure 6.

yield (weight) : 90g

yield (ratio) : 83%

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz, δppm) : 4.59 (d, 6H), 3.91 (d, 2H), 2.05 (s, 3H), 1.86 (d, 6H), 1.73 (q, 6H)  
IR spectrum : 2910, 1728, 1325, 1310, 1227, 1046, 1036, 868, 847 (cm<sup>-1</sup>)

5 Example F2



Bis(1-oxo-2,6,7-trioxa-1-phosphabicyclo[2.2.2]-oct-4-yl)methyl adamantanecarbonate was prepared according to the reaction scheme.

10 Into a three-neck flask (500ml) equipped with a dropping funnel, a Dimroth condenser and a CaCl<sub>2</sub> tube, were fed 86g (0.48mol) of 2,6,7-trioxa-1-phosphabicyclo[2.2.2]octane-4-hydroxymethyl-1-oxide and 76g (0.96mol) of pyridine, and the reaction mixture was stirred at 60°C.  
15 Into the reaction mixture was added dropwise 50 g (0.19mol) adamantanedicarboxylic dichloride dissolved in 100ml of acetonitrile, and the reaction was effected at 85°C for 8 hours.

The reaction mixture was cooled to room temperature, 20 and 500ml of ethyl acetate and 500ml of water were added to the reaction mixture, and the mixture was put into a separatory funnel to isolate an organic layer. The organic layer was washed with 500ml of water one time, 500ml of

15 % by weight  $\text{Na}_2\text{CO}_3$  aqueous solution two times, and 500ml of water one time in this order. The organic layer was dried with sodium sulfate, and the solvent was evaporated to obtain white solid. The obtained solid was washed with 5 methanol and was dried under vacuum.

yield (weight) : 88g

yield (ratio) : 84%

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz,  $\delta$ ppm) : 4.61 (d, 12H), 4.02 (d, 4H), 2.48 (s, 2H), 2.39 (s, 2H), 2.09 (q, 8H), 1.51 10 (s, 2H)